Water Management Traditions in India

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UMA SHANKARI
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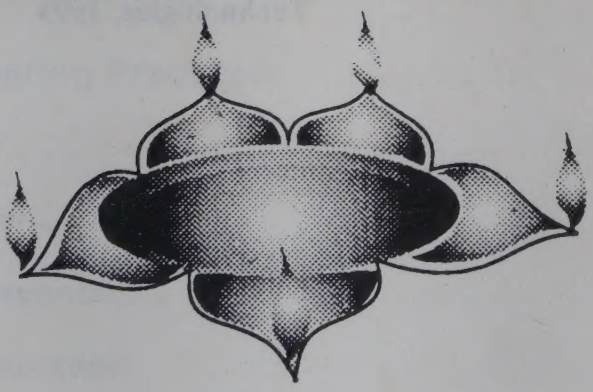
1993



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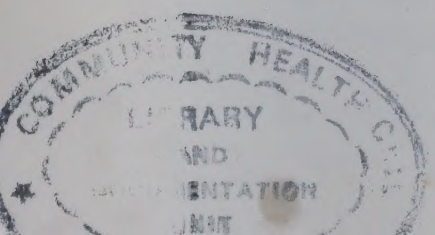

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Preface

It was felt that the Congress on Traditional Sciences and Technologies of India (to be held in IIT, Powai, Bombay between Nov.28 and Dec 3, 1993), would be a suitable occasion to put together the available material on Indian traditional water management systems, which are at present lying scattered. Hence this book was commissioned.

There is nothing surprising about the richness and variety of traditional water management systems in India. Water is such a basic need, that all societies, including our own, have tried to tackle it, each under its own special circumstances, and each in its own ingenious ways. But in the recent past we seem to have fallen into a collective amnesia - we seem to have forgotten about their usefulness in our daily lives, their ecological soundness and their scientific and technological knowledge base. This book would have achieved its purpose if it reminds each one of us to recollect our rich heritage in water management techniques; to preserve them and modify them suitably, wherever necessary.

The source material for this book, except for a few, have mostly been generated within the last ten to twelve years. The importance of these studies should be understood in the context of rising dissatisfaction with conventional water resource planning and increasing awareness of environmental and social costs of 'development'. Traditional water management systems can be considered as one of the emerging alternatives in the water management scenario. The studies deal more with social and management aspects than ecological and engineering

aspects. A lot more detailed investigations are needed to firm up the conclusions.

The book is divided into 2 parts. Part I deals with social and management aspects. Part II deals with engineering aspects. Ms.Uma Shankari, being a social scientist by training, authored Part I and Ms.Esha Shah, an environment engineer by profession, is the author of Part II.

But for the interest shown by the PPST Foundation, this book would not have been written. We are particularly thankful to Prof.Ashok Jhunjhunwala for the interest and effort he took to bring out this book.

We are most deeply indebted to Prof.Nirmal Sengupta for his constant encouragement and support. He not only made detailed comments and suggestions on the earlier drafts, but also helped us to collect scattered material and spared his valuable time for lengthy discussions.

We specially thank Ms.Paroma Deb, who designed the cover page and helped with some of the sketches. The drawings in Part I are prepared by Mr.A.Nagarajan, and the illustrations in Part II are prepared by Mr.Sam Joseph. To both of them we extend our warmest feelings of appreciation.

Madras,
November 1993

Uma Shankari
Esha Shah

Part – I

Management Practices

Background

Countries of the world have veered round to believing what is good for the West is good for the whole world. This is somewhat surprising because all through history societies ploughed their own ways and carved out their own identities-often tortuously, through internal and external strifes, through collective (un)conscious introspection and innovation. But within a matter of five to eight decades we have been persuaded into thinking that we should "develop" and "modernise" more or less in the same way-in form and content-as the West, the voices of dissent notwithstanding.

So we have had and continue to have "development projects", by which we have imported on a massive scale technologies, institutions and values. In the process, indigenous technologies and institutions, norms and values, which have been developed through centuries have been dumped into the garbage bins of history. Irrigation technologies and water management systems are no exception.

Traditional technologies of *eri* and *kulams, kuntas* and *kattas, tankas* and *naadis, jheels* and *johads,* Persian wheels and

mohtes, mud pots and copper vessels have been discarded in preference to dams and canals, tubewells and borewells, drips and spinklers, refrigerators and water filters. But have we done it judiciously, carefully, after due scrutiny?

As a matter of fact (re)discovery of our Traditional Water Management Systems (TWAMS) is only ten years old. A few studies of historical and social aspects of TWAMS have been conducted, but systematic studies of the engineering and environmental aspects are yet to be started. In what follows, a state of the art of these studies as well as of the systems have been described. This booklet is more an invitation to understand TWAMS rather than a comprehensive description. It would have served its purpose if it disturbs the proverbial hornet's nest of irrigation thinking.

We, the Rain Indian Tribe....

The ultimate source of all fresh water is rainfall. Water management implies a good understanding of rainfall, apart from dealing with streams and rivers.

India's normal rainfall is 200 cms i.e 400 million hectare metres (mhm). India's annual requirement by 2000 AD is about 100 mhm. We are 300 mhm in excess! Are we? No....For, the utilizable rainfall is only 105 to 115 mhm. What happens to the rest? Part gets immediately evaporated; part percolates into deep aquifers; some goes to build up soil moisture; and some flow away as floods.

LESSON: *We have to harness rain water - as much as we can, use it as wisely as we can.*

We the Rain Indian TRIBE

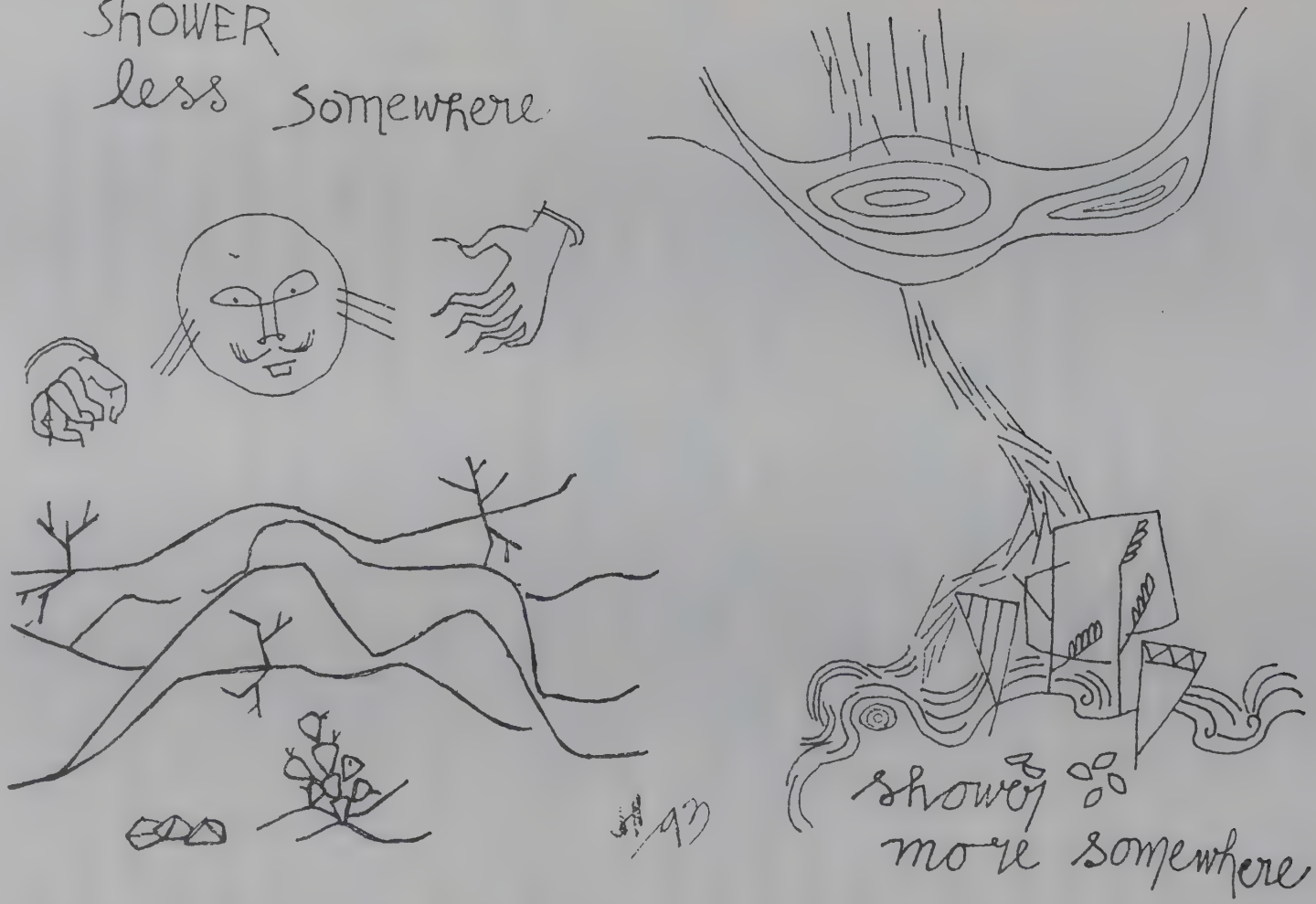
Shower more somewhere, shower less elsewhere, but when we rain, we pour!

Rainfall varies from 1140 cms in Cherrapunji to 300 cms in Mangalore to 20 cms in Jaisalmer. While most of the regions get their rain from South West Monsoon, some regions get their rain mainly from North East monsoon. Duration of rainfall varies from 15 days in some places to 2 months in some other places to 5 months in some.Rainfall also varies from year to year, the coefficient of variation ranging from 80% to 15%.

In spite of these variations the intensity of rainfall does not vary much. Intensity or mean rainfall per day is around 20 mm whether it is Mangalore or Jaisalmer, Bombay or Bangalore (Mean intensity of rainfall in the plains of Western Europe including England is about 2 mm). Moreover rainfall also occurs in heavy short spells of a few days or even a few hours - on an average of 300 hours or 12 1/2 days throughout the year. Even out of the 300 hours half of the rain falls in less than 30 hours. For example half of Bombay's rainfall (100 cms) occurs within 30 hours spread over a rainy season of 100 days.

For a non-rainy day.....

Short spells of heavy rain result in sheet flows, flash floods, greater land and soil erosion, less percolation. These characteristics of Indian rainfall have had definitive impact on agriculture, water control structures and water management practices. They have forced us not only to store the rain water for the non-monsoon periods but also to store it **wherever** it rains, in hundreds and thousands and thousands of small reservoirs. They are known by different names in different parts of


SHOWER
less somewhere
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shower
more somewhere

India- *eri, kulam, jheel, sagar,johad,talab, sar, nadi, khadin, kund, cheruvu, kunta, voddu, katta, kere ,pukur, bandh, dighi ahar,.....* Rain water is also stored in irrigated fields, especially in paddy fields, within their high bunds.

This way we not only stored water for the non-rainy days, but probably reduced damage from flash floods, allowed for more percolation, built up soil moisture and greater greenery, reduced soil/land erosion, maintained atmospheric humidity regime.

It is no wonder that the Indian landscape is dotted with innumerable tanks and ponds. Do not make a mistake: they are not always natural depressions where water stagnates; they are for a very large part man-made lakes. The streams and rivers have been carefully trained to feed these lakes as well as the lands adjacent.

In fact smaller reservoirs scattered over the whole watershed may be a better technological choice. All our dams can store at any point only 8 to 12% of the rainfall which occurs in the catchment. The Sardar Sarovar Dam will capture at the most 20%. The rest of the rain has to be allowed to flow away if the dams have to be saved

> An analysis shows, that on the average the Dam would be full by 15th August of each year and that thereafter, fifty per cent of the inflow, an amount sufficient to fill the reservoir three and a half times over, has to be let off via the spillway. If we take the rainfall over the whole catchment, the amount of water used by the Sarovar will be only 20%. The case with other rainfed dams, is worse, on the average the rainwater utilised by them ranges from 8% to 12% according to a study conducted by the Institute of Tropical Meteorology, Pune. Allow me to repeat that this is due to the characteristics

of our rainfall, very heavy rainfall occurring during a few days of the monsoon season.(Pisharoty 1990:52)

Contrast this with the observations of Major R.H.Sankey, Chief Engineer in Mysore in 1866:

> "Of the 27,269 square miles covered by Mysore, nearly 60% has, by the patient industry of its inhabitants been brought under the tank system. Unless under exceptional circumstances, none of the drainage of these 16,287 square miles is allowed to escape. To such an extent has the principle of storage been followed that it would now require some ingenuity to discover a site within this great area suitable for a new tank" (quoted in Vani 1992).

Even in areas of very poor rainfall people devised ingenious ways of storing water for the non-raining periods eg. the sub surface *tankas*,the roof water harvesting systems, and the step wells, apart from ponds and lakes of Western India.

Some of these lakes were so large that they could store water for 18 months to 2 years. This was important given the high coefficient of variation in rainfall. Every other year could be a drought year and necessary arrangements for water had to be made. The Gaya district in Bihar is said to have escaped the severity of famines in the 19th century thanks to its network of *pynes* and *ahars*.

Living between water surplus and water deficiency

Living alternately between floods and famines is not something new to us. Irrigated agriculture has always existed side by side with dry and rainfed agriculture; and agriculture with livestock farming. Dry crops such as millets, pulses and oil seeds are as important as irrigated crops. Water abundant regions specialised in wet crops, water deficient regions in dry crops. But even in water abundant regions, certain dry crops were

always sown while in water deficient regions, patches of wet crop cultivation was very common. Intercropping and crop rotation between wet or dry crops are even now widely practised.

A typical Indian village was surrounded by wet lands and dry lands, gardens, pastures and forests, ponds and lakes if not rivers and streams. The typical Indian diet is a largely vegetarian and included a mix of cereals, pulses, vegetables and livestock products of milk, curd and ghee.

Food preservation is an obsession with Indian women - another non-rainy day syndrome - but that is another story.

What are the options to get out of periodical scarcities? One is to bring more and more land under irrigation. This is the choice that has been assiduously followed. But this usually makes dry crops like millets, pulses and oilseeds disappear in favour of high value crops like sugarcane, tobacco, cotton and coconuts. Precious and cheaper sources of proteins and fats become scarce. This is especially serious because sources of animal protein are already scarce and dear in our country. We need to pay more attention to increasing yields in dry and rainfed agriculture, through forests and soil moisture conservation techniques .

Fine tuning with Soils and Seasons

A wide variety of water control structures and water management practices are to be encountered in India, which reflect a fine tuning between terrain, soil, climatic factors, water availability and crops. Whitcombe describes agriculture in the Doab region as follows:

Throughout the provinces, the fasli (agricultural) year began with the month of Asarh (June-July). On soil moistened by the first falls of the annual monsoon rains, farmers sowed their kharif (autumn) crops: first, early dhan (paddy), where the land was low-lying and the water supply abundant, and on drier, more elevated tracts, small millets and maize. Later in the month, the longer-maturing staples were sown. These were chiefly the millets jowar and bajra, the pulses urd, mash, and mung, and, in "wet" tracts, jarhan (transplanted paddy). These late kharif crops provided the staple food supply for the bulk of the population. In addition to these food grains, later kharif sowings also included cotton and indigo, which required intensive cultivation. The harvesting of the kharif spread over the months of Bhadon, Kuar, and Kartik (September-October). Where no serious climatic disorder disturbed the agricultural cycle, the timing of the harvest was fixed at the beginning of the season by the coming of the rains. Generally, harvests in eastern districts preceded those in the west by some three or even four weeks. Farmers in south-western districts harvested their crops before those to the north by approximately the same amount of time. Where the monsoon was delayed, or when heavy falls of rain in late July or August hindered the ripening of the kharif, harvests were protracted in consequence. In eastern districts, for example, such climatic disorders could mean the delay of harvesting until early in Aghan (November).

Where soils were rich enough to stand intensive cultivation without risk of exhaustion, the crops of the second harvest of the year - the rabi (spring) harvest - were sown on plots cleared of the previous kharif. Such rich dofasli (double-cropped) land was by its nature confined to a small proportion of the cultivated area of each district. Rabi crops were commonly sown on plots set aside for that harvest and prepared whilst the kharif ripened. The chief rabi staples - wheat, barley, peas, and gram - were usually sown in mixtures of two to three crops per plot. They needed light rains during Kuar (September-October) for their germination, and further showers during Aghan and Pus (December-January) brought them to maturity. The very best rabi was raised on irrigated land, watered two or three times during the season. Shelter for the growing kharif and rabi grains was commonly provided by the staple pulse arahar, which was sown together with the later kharif and harvested with the rabi,

enriching the soil on which it grew by leaves cast off during its maturity. Rabi harvesting lasted throughout the months of Chait, Baisakh, and Jeth (March-May), the local timing again varying from east to west and south-west to north as for the kharif. The cultivation of sugar cane stretched beyond the confines of a single fasli year. Early in the hot months, from Chait (March-April), land on which the cane was to be planted was ploughed up repeatedly - seven times at least - and left fallow during the rains, after which it was ploughed once more. The canes were planted out on it the following Phagun and Chait (February-March). Irrigated frequently during the subsequent hot season. Sugar cane reached its maturity in the following cool months. The long operations of the cutting and crushing of the cane and the boiling of the extracted juice (ras) into molasses (gur) began in Aghan and lasted well into the following Chait.

Cropping patterns of staples followed the natural conditions of each locality. From an observation reported from Muttra district in 1879-which can be taken as representative in this respect of the provinces as a whole-it is clear how the variety of soils and the extent to which irrigation was readily available determined the basic pattern of agricultural prodcution:

(1) Where water was far from the surface and irrigation consequently difficult, kharif crops outnumberd the rabi: a small area only was sown with wheat (which required at least two waterings); a (correspondingly) large area was sown with gram.

(2) Where the natural soil conditions were good, jowar (which required merely good soil and little attention) was grown extensively and bajra only nominally, of the staple kharif millets.

(3) Where no jhils (lakes formed by rainfall collecting in hollows in the ground) existed and the climate was generally dry, paddy was not grown.

(4) Where water available for irrigation was brackish, sugar cane was rarely grown.(Whitcombe 1971:21-23)

Such micro-adjustments are possible only in small decentralised systems. It is no accident that even today productivity under well irrigation is double that of canal irriga-

tion. Even where canal irrigation was practised extensively since ancient times, as in Kaveri delta, farm plots tended to be small. This is so even today despite introduction of other modern inputs like chemical fertilizers and pesticides. This is especially true of rice cultivation, where water application needs to be quite precise.

Agriculture in West and East

The conditions in our country (and in fact in all tropical countries) are so different from those of Europe that many of the agricultural technologies developed in the West are not applicable here.Irrigation is not in fact necessary in most European countries whereas it is often crucial in tropical countries.

> Northern Europe has a short growing season, and the staple cereals, wheat, barley and rye, bear heads with relatively few grains - at best a few dozen, compared with the several hundred grains in each panicle of rice or millet - and usually only a single head on each plant. This may seem a trivial point, but it affects yields and means that a much higher proportion of the harvested crop must be kept for seed-grain. The climate of Northern Europe does not permit more intensive cultivation than three grain crops in two years, but even this is a very recent development which depends on the use of fertilisers and scientific crop rotations. Before the seventeenth century the commonest method of fertilising grain fields was to pasture livestock on the fallows; thus corn could only be grown one year in every two or three. Under these conditions, the farming system of Northern Europe used land extensively and could not support high population densities. The size of a family subsistence holding was neccessarily large: a feudal manse in the ninth century was often as big as 40 hectares
>
> Livestock played a crucial role in this farming system. Firstly they were the chief source of manure, and the right to fold the village flocks on one's fallows was hotly contested in mediaeval times. Since

yields were so low, draught animals were essential, for it was impossible to till sufficient land for subsistence by manpower alone. Though in some regions plough-teams consisted only of a pair or two of oxen, in heavier soils between eight and a dozen oxen might be needed for a team, ... Where draught animals and heavy equipment like turn-ploughs and harrows play such a crucial role in agricultural production, it is clear that large farms, which can afford more animals and equipment and can organise their use more efficiently, will have a significant advantage over small holdings....

Rice is a tropical crop, and in many areas two or even three crops a year can be grown, though where natural rainfall is the only water supply a crop planted in the monsoon season is most common. One panicle of rice usually contains 400 or 500 grains, and each plant may have several panicles. It is therefore not necessary to reserve a large proportion of the crop for seed; returns of the order of one hundred to one are far from exceptional.The water supply is the most important factor in rice cultivation: although most varieties of rice respond well to additional fertilisers, the water usually supplies all the nutrients required for healthy growth.. The area that a wet-rice farmer cultivates is therefore not dependent upon adequate supplies of manure, and livestock play a much less important role than in Europen farming systems. Furthermore, since rice is by nature a relatively high-yielding crop, and since the water's fertilising power enables irrigated fields to be cultivated continuously without fallowing, the area required for a subsistence farm is comparatively small. Even where single cropping is practised a farm of two hectares will support a family Areas where wet-rice cultivation is practised can generally maintain higher population densities than wheat regions.

.....Irrigation became a necessity as rice farming spread from natural swamps to drier areas. Asian irrigation systems range in complexity from the tapping of mountain streams (the archetypal case in Bali) and the digging of a farm or village tank (common in Central China, early Japan and Ceylon), to the elaborate networks of canals upon which Wittfogel based his theory of hydraulic despotism. In the high-rainfall tropics, where most Asian rice is grown, it is usually possible for the local inhabitants to organise small-scale irrigation facilities of some sort on their own initiative. But even though large scale irrigation works are less crucial to agricultural production than

they are in certain low-rainfall zones, there is no doubt that many Asian rulers have seen advantages in undertaking such projects (Bray 1983: 5-10).

Dams for power, dams for irrigation

One of the most important water control structures is the dam. Dam technology is an ancient one. The earliest recorded dam is believed to have been built on the Nile river about 2900 BC to supply water to Memphis, the capital of king Menes. In India a weir which is now called the Grand Anicut was built across the Kaveri in 2nd century AD by Karikala Chola. It was greatly improved by the British and is functioning even today. The numerous tanks to be found all over India are essentially dams of smaller height. They have stood for centuries and are operational even today.

The modern dams of great heights perhaps has its antecedents in the water mills of Europe. Water was used in Europe extensively as a source of energy to run flour mills and myriad other industries .

> The mill thus becomes a sort of standard measure of the energy supply in pre-industrial Europe..... Towards the end of the eighteenth century there were, according to records for Galicia (which had come under Austrian rule). 5243 watermils (and only 12 windmills) in an area of 2000 square leagues and for a population of 2 million. This looks an enormous figure at first sight, but then the Domesday Book of I086 records 5624 mills serving a mere 3000 settlements south of the Severn and the Trent, and one has only to look out for the innumerable little wheels visible in so many paintings, drawings and town plans to understand how widespread they had become. If the ratio of watermills to population was the same elsewhere as in Poland, there would have been 60,000 in France and not far off 500,000 to 600,000 in Europe on the eve of the industrial revolution (Braudel 1985: 357).

In the beginning of 20th century huge dams of great heights came to built to generate electricity. The question of height of the dam or drop surely makes more sense in the context of power generation rather than irrigation! Indigenous dams which were built for irrigation purposes impounded more water not so much by increasing the height but by lengthening the bund (length of the bund also helps to deflect the stresses and strains on the bund). The Veeranam Tank in Tamil Nadu has a bund of 16 Kms length. It was built from 1011 AD to 1037 AD. Dams of longer bunds and smaller heights were built in valleys and plains where irrigation was both feasible and in fact necessary; whereas, modern dams have to be built in hilly tracts and long canals have to be built before water reaches areas to be irrigated. This is not so much an argument against modern dams of great heights as to plead a case for studying the scientific rationale behind indigenuous water control structures. Modern dams evolved in a certain historical contexts and for a definite technological and social purpose. Listen to Theodore Steinberg:

> Hoover Dam is indeed a wonder. It took five years to build, contains over 4.5 million cubic yards of concrete (more than the Bureau of Reclamation used in all the dams it built until that time), rises to a height of over 700 feet, cost more than fifty million dollars, and claimed over 100 lives. When it was finished in 1936, it ranked as a singular engineering feat, a symbol of American ingenuity and the mark of a nation that was fast rising to global dominance. But Hoover Dam was only the beginning. Over the course of Wallace Stegner's life (he was born in 1909), a long list of dams went up across the waters of the Colorado River Basin: Parker Dam. Imperial Dam, Davis, Laguna,Navajo, Flaming Gorge, Blue Mesa, Marrow Point, and ultimately, Glen Ganyon, itself a mere 16 feet shorter than Hoover. Welcome to the World's Fair.

> The guiding philosophy behind this profusion of dams was the simply will to control and dominate the natural world. That is a very old idea, arguably as old as the human species, which from the beginning has sought to control nature to survive on this earth. But the technological conquest of nature in the 20th century has had a scale, an arrogance, with few rivals in history. . Perhaps never before has the will to conquer nature been so consciously and purposefully expressed, so matter-of-fact. What was being expressed here was arrogance by design. The Hoover Dam that Stegner and the thousands of visitors before and after him viewed was supposed to signify greatness, power, and domination. It was planned that way.

Similarly extension of canal irrigation in United provinces in India had a definite purpose. Whitcombe argues that the British administration's over-arching concern for high revenues saw indigenous agriculture as a victim of capricious monsoons which compelled the administration to extend relief, remissions and suspensions of revenue in a little over 20 years from the opening of Ganges canal in 1854, the second largest canal system in India and world, 5601 miles of canals had been constructed irrigating an area of 15,00,000 acres at a capital cost of 45,00,000 pounds sterling, While expansion of irrigated area was achieved, millets and pulses, on which the poor depended for food and fodder, disappeared in favour of high value crops such as wheat, sugarcane, cotton, indigo and opium. Overcropping led to deterioration in fertility. Rise in water table led to water logging and salinity affecting an area of 4000 to 5000 square mills converting it into "howling wilderness".Whitcombe's arguments have recently been contested by Stone (1984) who has tried to show that canal irrigation in fact introduced a great deal of dynamism in the economy of United Provinces, over and above the deleterious effects it had. The debate is only a pointer to the need to assess historical "achievements" carefully and to learn the right lessons from it.

Management Traditions

Indigenous irrigation systems were often large complex systems involving several user-communities living in different villages. These large systems were often sponsored by the state - kings, queens, local chieftains, zamindars, etc. The state interest in development of irrigation systems is obvious: by increasing land under irrigation it enhanced its own revenues (Revenue assessments of wet lands have been traditionally higher than that of dry lands). Its genius lay in the fact that there was an incentive for other kinds of sponsors and builders too in it: the state granted land as reward to the builder and/or remitted taxes on it. Add a high degree of spiritual merit to the construction of water resources the result was as expected: construction of water resources was sponsored not just by kings and chieftains but much more importantly by village communities, temples and "philanthropic" individuals, in fact any one who dared to! The public park in front of Aurobindo Ashram in Pondicherry bears an inscription stating it was a tank built by a dasi - a temple dancer-courtesan. An inscription in Karnataka (1100 AD) records of a village watchman

So, let us store you where and when you POUR
aw 93

building a tank and a shrine. Another inscription records that the tank was built by an elephant driver.

South Indian inscriptions are full of records of water works sponsored by the state: all the dynasties, Pallavas, Rashtrakutas, Cheras, Cholas, Pandyas, Kadambas, Gangas, Chalukyas, Rashtrakutas, Hoysalas, Vijayanagara Kings, and Muslim Sultans were in it. A detailed coherent history of irrigation for other parts of India are as yet rare and difficult to come by (and this monograph has to largely depend upon South Indian studies for its arguments) but there are many scattered references of state involvement in irrigation, such as, the famous instance of old Jamuna canal built by Firoz Shah Tughlaq, revived and extended later by Shahjehan. Many of the bigger kuhls or guhls in Himachal regions were sponsored by kings, zamindars were actively involved in the construction and maintenance of ahar-pynes in Bihar.

Although the state was very much in evidence in construction of "big" works, innumerable smaller works were constructed at the initiative of individuals and local communities; and operation and maintenance of both large and small works were mostly in the hands of local communities.

> Arthasastra recommends that the king shall construct reservoir (setu) filled with water either perennial or drawn from some other source. Alternatively he might provide with sites, roads, timber and other necessary things to those constructed reservoirs of their own accord.
>
> Arthasastra also outlines certain punishments for "defaulters" "Whoever stays away from any kind of cooperative construction (Samabhuya setubandat) should send his servants and bullocks to carry on his work, should have a share in the expenditure but should have no claim to the return".

"The natural over flow of water from higher tank to a lower tank shall not be stopped unless the lower tank has ceased to be useful for three consecutive years". Severe punishment is recommended for such an offence. The same punishment is meant for emptying a tank of its water. Persons letting water out of turn or stopping water from the fields of others during their time are to be fined.

Powers of village communities vis- a-vis water resources

Village communities enjoyed wide ranging powers in relation to their common property resources like forests, wastelands, pastures and water bodies. South Indian inscriptions record purchase and sale of (a) entire tank systems including tank, ayacut and foreshore (b) shares of water from other village bodies, (c) share of fisheries, (d) all kinds of land to raise funds for various purposes relating to the tank. They were also empowered to levy various cesses and to grant exemptions from taxes and dues.

Besides these assignments and remissions of taxes and dues, the village assemblies became responsible for another class of tax remission. This latter type helped the assemblies to raise large amounts: i.e. in lieu of a lump sum payment made in advance to it, the assembly undertook to pay all dues to the local and central governments on particular plots of land for all time. The lump sum in these instances was the capitalized value of the annual dues chargeable to the land and was generally called *irai dravyam or irai-kaval*. Such advance payment in lump sum of future taxes was due to two general causes. First, persons who endowed charities for setting apart land often desired to secure for such land freedom from all dues and imposts, and the common way of doing this was to pay their capitalized value to the assembly of the village where the land was located making responsible for all future payments. Secondly, the assemblies on their own initiative often raised money in this manner for immediate capital expenditure for public purposes which could not be financed otherwise" (Vani1992 : 21 - 22).

Farmers' Associations

A long tradition of farmers' associations for the construction and maintenance .of water works exist all over India. They were referred to as *panchayats* in Karnataka and in Maharashtra; *nattamai, kavai maniyam, nir maniyam, oppidi sangam* in Tamil Nadu. Historical records of Tamil Nadu speak of *eri variyam* (tank committee) and *eri merai* (tank dues).

Farmers' associations in small water resources involving a few families of ayacutdars tend to be informal associations. The farmers who have the biggest holding under the command usually takes charge of conducting the repairs and maintenance in consultation and cooperation with the other ayacutdars. Such 'anonymous' or nameless organizations are far too numerous, given the fact that tanks or canals which irrigate very small ayacuts are the most common in India (Out of 43,477 tanks in Karnataka, nearly 50% irrigate less than 10 acres!). In the case of water works which serve a single large village, the village panchayat or gram sabha may coincide with the irrigation association. (eg. *panch committee* in *Phad* system of Maharashtra; *nattamai* in Tamil Nadu).Where a water source serves more than one village, representatives selected from each village or from the ayacutdars served by each of the channels or sluices are represented in the executive committee(eg. *oppidi sangam* in Tamil Nadu).

Some of these farmers' associations have so modernized themselves that they operate exactly as any other "modern" organization: they conduct general body and executive meetings, record minutes, pass resolutions, keep audited accounts,

conduct elections to elect the office bearers, employ a staff on monthly salaries or daily wages, etc. etc.

What are their functions? Farmers' associations typically decide upon and execute the allocation or the distribution of water in the ayacut, organize repairs of maintenance works and settle disputes between ayacutdars. They appoint and supervise irrigation functionaries, formulate rules and norms for water distribution, collect funds for maintenance works, organize the maintenance works, hear complaints from farmers and settle them. It is very important to remember that there are great many variations in the way farmers' associations function. But as long as a certain level of consensus among ayacutdars prevails, they function efficiently and smoothly.

Why do farmers' associations collapse?

All over India farmers' association have ceased to function. The reasons are many.

In the pre-British period, the village as a whole was responsible for payment of land revenue to the state. This gave them considerable freedom in allocation of land and water, sale and purchase of the same and remission of taxes in relation to them. The British made radical changes in revenue administration. They shifted revenue responsibilities to individuals - Zamindars in Zamindari system, individual farmers in Ryotwari system. This greatly undermined the corporate character of village community.

During the British period village common properties came to be vested with the government. The village communities lost control over them and gradually interest in maintaining

them. British government also curtailed taxation powers of village panchayats, so that even if the village communities were interested in maintaining the water resources, they could not compel the farmers to pay taxes or levies.

Hereditary village officers were made "government officials" by the British government. They became accountable or acted as spokesman of the government rather than the villagers. In post - independence period many state governments have abolished the post of hereditary village officers and have appointed "village accountants". This has left a vacuum in village leadership. The village accountant or the Village Development Officers have no locus standi, no stakes in village development, is on a transferable, nine to five job and is accountable to the officials of his department rather than to the villagers.

Abolition of *inams* or grants to village servants dealt another blow. For instance, the *nirkatti inams* have been abolished and the *nirkattis* have been made the legal owners of these *nirkatti inams*. While individual *nirkattis* have benefited from this, the institution has suffered: the villagers have no right or control over the *nirkattis* except by appointment or payment. The *nirkattis* being poor and landless, have of the sold away this land for emergencies.

Expansion in private sources of irrigation like wells, tubewells, borewells is by far the most important cause of deterioration of common/public water resources. Every farmer dreams of having his own well and "doing his own thing" He then does not have to cooperate, adjust or accommodate with the other farmers.

Irrigated agriculture was by and large oriented to rice cultivation in the past. Other crops were cultivated in wet lands only when water was not adequate for rice (of course this may vary from region to region). Today cropping pattern has so diversified that farmers grow different crops with different water requirements within the same command area, depending upon their economic condition or price signals. This disturbs the previous water sharing norms or rules.

Lack of stable water supplies is another problem which weakens motivation to collective action. This happens especially in drought-prone areas where the tank may fill up only once in few years. Drought-proneness has increased due to deforestation, because of which rain water runs away too quickly, allowing little time to percolate or build up in the reservoirs. This also happens when new projects come up in the upstream which affect the supplies of tanks downstream. Government keeps building new check-dams regardless of their consequences, in response to pressure from the public or politicians.

Diversification into non-agricultural occupations, especially near urban centers also weakens interest among farmers towards agriculture and in turn towards farmers' associations.

Irrigation functionaries

A set of irrigation functionaries to look after the day-to-day functioning of the irrigation system or water work have long existed in different irrigation systems. They are known *nirkatti, nirganti, nir paychi, niranikkams, kambukatti* in tank irrigation, *patkaris* and *havaldars* and *jagalyas* in *phad* system, *kohlis* in

kuhl system. They had the responsibility of irrigating every field in the ayacut according to its requirement or the norms laid down by the farmers' associations.

Nirkattis were recruited traditionally from the caste of Harijans who were also the landless community. This custom is explained by the ayacutdars as: since the Harijans do not own land, they would have no personal stakes or caste patriotism and they can be expected to be impartial in water distribution.

The *nirkattis* in their turn took pride in conducting their work impartially. They functioned with certain degree of autonomy. For instance, only they could close and open the sluices of the tank or vents in the fields. The farmers were not allowed to do this. Once the norms of distribution were laid down, the *nirkatti* followed them regardless of its effects for individual farmers. If farmers, in their anxiety to ensure adequate water to their fields, tampered with the sluices or water courses, *nirkatti* could report the matter to farmers' association and the farmer had to face severe rebuke or even fine. The farmer in turn had the right to complain about the *nirkatti* if he was found to discharge his functions inadequately. If found guilty, the *nirkatti* could be punished.

Nirkatti is traditionally a hereditary post reserved for Harijan castes, although today *nirkattis* are appointed from other castes for temporary periods on a contract basis. If the ayacut is small, then one *nirkatti* would suffice; if the ayacut is large then more than one were assigned the duties. They shared the command area among themselves and/or rotated the assigned area from year to year.

At the onset of monsoon, the *nirkatti* would summon the farmers through tom-tomming to clean the supply and field channels on a day fixed for the purpose. Once the tank was full, he opened the sluices or let the water to each field according to the soil, crop and its growth level or as advised by the farmers' association. He also had to guard the crops from stray cattle. For his labours, he was paid by the individual farmers, a fixed customary portion of the crop. In parts of Chittoor district of Andhra Pradesh, it was one headload of harvested sheaves of paddy crop per 10 guntas (66 cents) at the time of harvesting. One headload would contain 5 to 6 kgs. of rice. He was also entitled to the bottom layer of sheaves of grain stacked in the threshing floor. In addition, he was given one ball of jaggery per batch of jaggery made when sugarcane was grown. He was given a major share of the meat when animal sacrifices were made to the deities the bund.

Indigenous Irrigation Engineers

Construction of irrigation works is obviously a specialised skill involving knowledge of the terrain and hydrology. As Mukundan observes, in order to construct an eri or tank, today a modern engineer would have to make a topographic survey of the catchment area, the reservoir area or the command area to locate the site of the reservoir carefully; he must know the rainfall and the hydrological characteristics of the area very well in order to design the bund, overflow weirs, the sluices and the supply and field channels. The waterspread area and the area to be irrigated are also to be determined on the basis of the above data. The actual execution of the construction (of bund, sluices, waste weirs or the channels) is another for-

midable engineering task. "There is no reason to suppose the construction of erys would have been any simpler or would have been approached with any less skill on the part of the engineers of the old". (Mukundan 1988:17)

Who were these engineers? Although they performed a highly technical, specialised job, it is not clear who they were, how they were trained or how they went about their jobs. Scattered references give evidence to the existence of professional specialists. Singayya Bhatta was one such professional who lived in the 14 th century.

> The Kalludi (Gauribidanur taluk) inscription of 1388 A.D is well known. According to it, when Vira Harihara Raya's son Sri Pratapa Bukkaraya was in Penugonda city in order that all the subjects might be in happiness water being the life of the living beings - Bukkaraya in open court gave an order to the master of ten sciences, the hydraulic engineer (Jalasutra) Singayya Bhatta that he must bring the Henne (Pennar) river to Penugonda. Accordingly Singayya Bhatta conducted a channel to the Siruvara tank and gave the channel the name Pratapa Bukka Raya Mandalanda Kaluve. Singayya Bhatta must have had previous experience and must have been well known for his success as an engineer. (Dikshit 1993:69)

Some families also specialised in the art of construction of reservoirs. In one part of Chittoor district Andhra Pradesh, tanks are said to have been constructed by families of Yellamma Reddys.

Besides individuals and families, there were caste communities who specialised in earth and stone work called wadders and boyis. They undertook construction of tanks, wells, roads and works where earth or stone work was involved. Even today they are the main source of labour for Irrigation, and Roads and Buildings Departments.

Above all farmers themselves possessed intimate or considerable knowledge of the terrain and could very well plan or execute the work themselves.

Community labour

Voluntary community labour for maintenance of supply channels and fields channels was another important institution of the old days. Known as *kudi maramath* in South India, it was a widely prevalant practice all over India. Wherever, a repair work needed to be attended to, such as, cleaning of the supply channel, each family was required to send an able bodied person to contribute labour for the work. If it was not in a position to do so, it should send a hired substitute or contribute the money required for it.

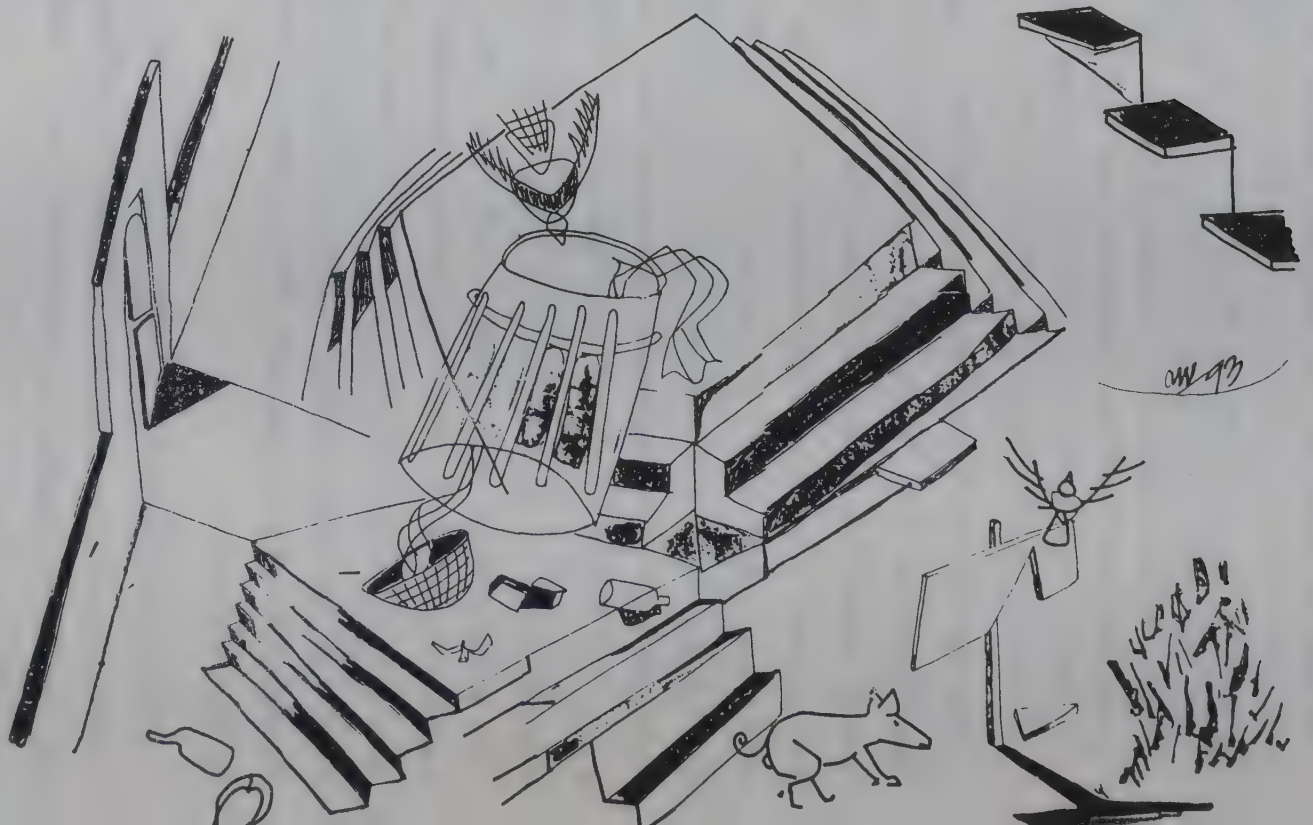
> The Bala ke karha channel (and other similar channels) are desilted and repaired once or twice a year. The first repair work is done after transplantation.Although the Bhumihars invariably engage agricultural labourers for cultivation,they regard all the manual works pertaining to irrigation as their own duty.Their is no fixed share. On the particular day all ablebodied members of the landowner families turn up. Though the work might meet merely 15 to 20 labourers a day, nearly 50 people turn up. So the work is done at leisure in a spirit of fun which motivates the people to participate. It is interesting to note that there does not seem to be a system of penalising the absentees. However, households unable to send someone pay cash as a token gesture to show their participation. The fine, thus is voluntary and not charged at any specific rate.
>
> For the construction of the check-dam on Supi desiyain pyne (for diversion of water into the Maniwanan tank), communal labour is required on a much larger scale. The landowners of Bala Ke karha take the lead here as well. These landowners are the ones who come to know immediately about the condition of flow due to their proximity to the tank and the diversion structure. They schedule the work for one Sunday and send a drummer to inform the beneficiaries

of the tank residing in other tolas of Maniawan and in other beneficiary villages. Here too, ther is no compulsion or recording of participation. Yet, nearly 300 to 400 people assemble on the fixed day near the dam. The whole work might have been done by a third of them in a single day. The atmosphere is almost like a festival. A drummer constantly drums a rally tune. the traders distribute tobacco free of cost. From time to time war cries are heard. Recently there was inter-caste tension all over the state and backward castes from other localities refused to cooperate with the Bhumihars. Subsequently, the check dam was constructed badly because of the refusal. But the failure of tank irrigation, consequent upon that, led to greater cooperation next year. (Sengupta, 1991: 114)

The institution of *kudi maramath* suferred a setback during the British period. When the British Government took over village commons, it was recognised that it was the duty of the government to carry out the repairs, and users need to only contribute their share of the expenses. However, when the British government realised that repairs and restoration of hundreds and thousands of tanks would involve very great expenses, it tried to enforce kudimarath by compulsion and by legislation. This did not succeed and by the turn of this century government was forced to give up attempts to enforce *kudimaramath* and it resumed full responsibility for the maintenance of tanks. The institution of communal labour however, still survives in some areas or villages, although it is lost forever for official purposes. But in most of the villages it has all but collapsed.

This is also the story in other places in India. Ramanathan (1990) records that in many Rajasthan villages cleaning of agor or the catchment areas of ponds is very indifferently done except in rare cases.

tank beds OR garbage dumps?



Funds for construction and maintenance

Funds came largely from gifts of land made by individuals or the state. These lands were known variously as *dasavandam, bittuvatta, kattukodige, eripatti, kulapatti.* The term *dasavandam* means "10 in 100" and refers to a grant of land at 1/10 of the usual rates (of rent) to a person in consideration of his constructing or repairing a tank. Similarly the term *bittuvatta* refers to granting of a portion of land in the ayacut at a reduced rent in consideration for construction and upkeep of the tank. *Kodige* or *Kattukodige* also means grant of land free of tax or on a light assessment. The term *eripatti* translates as "tank strip' and may mean a strip of land meant for tank maintenance.

While gift of land was most common, gift of gold, money, paddy and other endowments were also quite common. Village communities also levied cesses for the purpose (called *eri merai* or *eri ayam*). Income from lease of fishing rights was also credited to the tank fund. Occasionally income from fines for violations of other village regulations were credited to the tank fund. It is estimated that about 4% of the village produce was alloted for maintenance of tanks in some parts of Tamil Nadu.

Distribution of water

When one looks at all the variations in the rules and norms of water distribution followed in different villages and regions, one is at first bewildered at their variety and differences. No system or no village seems to have the same rules of water distribution as another. However, when one goes to the depth

of it, what emerges is the principle of trade-off between equity of efficiency. All irrigation systems, whether it is tanks or *phads* or *kuhls* want to use the water efficiently and to prevent undue waste. At the same time all the farmers who are entitled to water, wish to get as equitable share as the system would allow. Incidentally in most of the systems the ayacutdars used to be of a homogeneous community, belonging to one caste or a kin group. Even where many castes were involved, the ayacutdars enjoyed a fair amount of equity in water distribution.

In normal circumstances in most villages water was distributed from head reach to tail end. While the head reach farmers got their water first, the tail enders benefited from seepage and needed less water to irrigate their fields. This situation was accepted by the farmers as a "fact of life". In drought years however, when water was not adequate to ensure irrigation for everybody, different rules came into operation. In some villages water distribution would start from the tail end. In others water was rationed by time. In some villages when water level went down below the sluice level, the farmers themselves took charge of the distribution temperarliy suspending the operations of the *nirkatti*. They emptied out all the water from the tank and distributed it equally in all the fields in the ayacut. This operation was called *kandavettu* in Tamil Nadu.

Earlier in many villages land was held in common by the village community and periodical reallocations were made to individual farmers for a specific period. This way everyone got his chance to cultivate "good" and "bad" pieces of land. In the phad system of Maharashtra crops were rotated among the

blocks in such a way that each block had a chance to cultivate water intensive crops only once in a few years. But every farmer had some land in every block so that he grew both dry and irrigated crops.

In tank irrigated villages of South India, the farmers' association or the panchayat would advise the farmers to sow only dry crops if the water was not adequate. This had to be followed strictly by every farmer. At the onset of monsoon the farmers would make an "eye estimation" of the water level and decide upon what crops to be sown, and at what intervals water was to be made available to each field. In some tanks the sluice walls bore certain marks or symbols which helped the farmer to decide the intervals. For instance, if the water level reaches 2 lines mark, water would be released once in 15 days ; if it upto 3 lines, then water was to be released once in 10 days; If water was upto the conch mark at the top it indicated full level and water could be released every day.

This kind of equitable sharing prevails in well irrigation as well. Very often several persons share a well, allocating water for fixed periods amongst themselves.Lot of give or take is noticed among them. Frequently the water sharers are connected through kinship but sometimes they are not. They work out a consensual pattern of water sharing which work most of the time, although disputes are not rare.

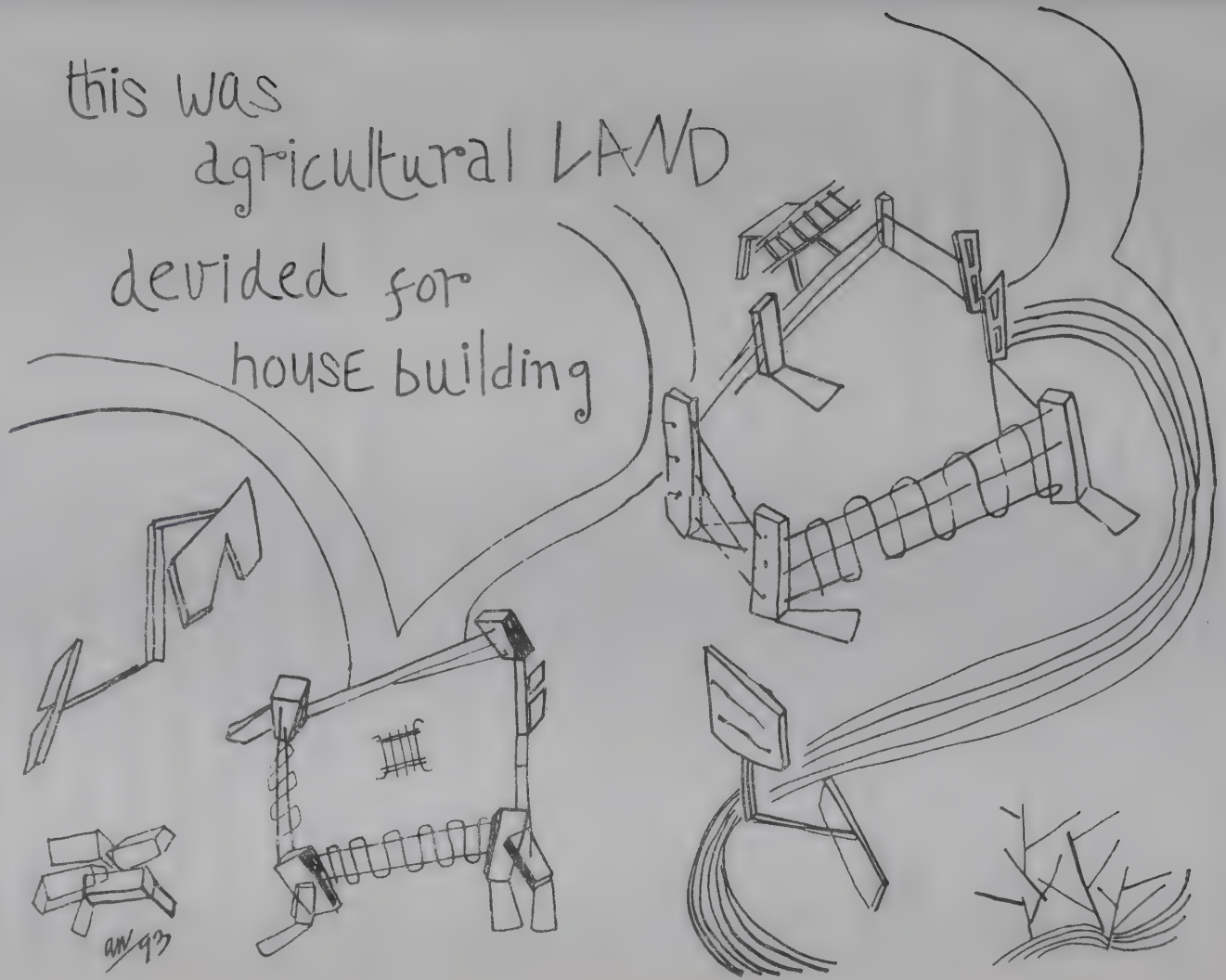
Such trade-offs between equity-and efficiency of water distribution as achieved by traditional water management systems is hard to come by in modern irrigation systems.Tail enders are doomed to lower supplies forever and the whole community of farmers is at the mercy of an impersonal bureaucracy which

formulates a rotation system or releases water on the basis of its own reasons. The farmers have no say in the matter. No wonder large scale bribing, water stealing and complaints of chronic water shortages are a characteristic features of modern irrigation systems.

Where a water source irrigates several villages detailed records of customary irrigation rights and rules for operating the hydraulic devices were produced (egs. *Riwaj - i - abpashi* -the book of irrigation customs in the Kangra district, Record of rights in the phad system). Even where written records were absent, definite rules of water sharing between villages prevailed and user communities protected their customary rights with a great deal of alacrity. They often appointed watchmen to see if any or stealing of water is occurring in the upstream villages. Disputes between villages over their shares of water are not uncommon. They were taken to the Zamindar or local kings for settlement.

The sacredness of water

Such an elaborate social system could not have been sustained unless it is backed up by strong religious traditions and sanctions. Cultural perception of water as a sacred resource is a widespread notion in India. Water and rivers are metamorphosed into anthropomorphic deities-*Varuna, Indra, Ganga (mma), Kaveri (amman), Samudra Raja,* etc. Rivers are worshipped at certain periods of the year or/and at the intervals of several years. *AdipPerukku* is a festival of the Tamils when the first flushesin the Kaveri are recognised and worshipped. *Kumbha Melas, Pushkarams, Mahamahams* are held at regular intervals at the banks of major rivers. When rains fail, *Varuna*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Japam is performed in the temples of South India. Temples are constructed at the banks of natural water sources like rivers, lakes, etc. If natural water bodies are not available, artificial water bodies are created - temple tanks, kunds, wells, etc. - inside or/and adjacent to the temples. The temple tanks of South India received their supplies from rivers and streams through underground channels apart from their own catchment.Water forms an important ingredient in Hindu worship. It is considered a purificatory substance par excellence and is used extensively in worship.

In tank villages of Chittoor district of AP, "bund deities" (*Katta meeda devarulu*) are worshipped. Potter is the priest in these rituals (the deities are terracotta images made by the potter) and *nirkatti* receives the major share of the meat in the animal sacrifice made to the deity. Besides, *Gangamma Jatras* are held for a favorable monsoon, among other things (like warding off epidemics, etc). Incidentally, washerman is the priest in the *Gangamma* worship.

Twams in post-independence period

Modern engineering approach to irrigation which was initiated in the beginning of the nineteenth century has continued in the post-independence period in spirit and substance. Large multi purpose dams, more canals, electrification of lifts, drilling of tubewells and borewells, and more recently, promotion of drips and sprinklers characterize the irrigation history of this period. A great expansion of irrigation bureaucracy, privatization of irrigation, disappearance of farmers' initiatives and decline of TWAMS are the concomitant developments.

The changes in the larger social scene have ofcourse reinforced these trends. Greater commercialization of agriculture (greater monetization of economy in general) and introduction of HYV agriculture have at once increased the demand for irrigation and worked towards privatization of irrigation. Private sources of irrigation like tubewells, drips, etc. give the farmer a great degree of flexibility in planning and executing a cropping pattern which he wants, whereas, in common/public sources of irrigation he has to coordinate/cooperate with others for fulfillment of his irrigation requirements, which necessarily limits his options. This has however contributed to neglect of community water resources,including canals, anicuts, tanks, ponds, community wells, spring channels, etc. Tank beds have become municipal garbage dumps, housing colonies, bus stations; supply channels and field channels have got choked with weeds and silt; catchment areas have shrunk; step wells have become historical ruins.

Greater centralization of polity has reduced village panchayats to the lowest administrative wings of the state governments with very limited powers and jurisdiction. Informal associations like caste councils have also lost their legitimacy and authority, with modern courts and police taking over their functions however ineffectively. New social bases of power has emerged replacing the old village leadership. The new leadership is oriented more towards competitive electoral politics rather than the old style politics of consensus. In the meantime government has so expanded in the name of development that there is little space for people's initiatives. People have come to expect the government to carryout every developmental/ welfare activity.

Government has no doubt expended a great deal of resources and effort in irrigation development. Its achievements are also fairly impressive. Yet an interesting fact remains that TWAMS constitute even today 20% of the net irrigated area and in some states they are the only source of irrigation.

Area Served by Private Canals, Tanks and Other Sources (1987-88)

State	Actual ('000 hectares)	As % of Net Irrigated Area
1. Assam	501	87.59
2. Jammu and Kashmir	172	56.03
3. Other Himalayan States	313	85.99
4. Kerala	153	50.00
5. Bihar	894	27.99
6. Karnataka	512	27.63
7. Tamil Nadu	626	25.68
8. West Bengal	482	25.22
9. Andhra Pradesh	785	23.30
10.Maharashtra	488	14.65
11. Madhya Pradesh	432	22.97
12. Orissa	234	13.99
13. Uttar Pradesh	423	4.21
14. Rajasthan	119	3.58
15. Rest of the States and UTs	107	14.50
All India	6241	14.50

Source: (Sengupta 1993:17).

In drinking water in spite of the ubiquitous handpumps, TWAMS still form the most important source.

In the past few years irrigation academics and bureaucrats have begun to take TWAMS seriously. Many seminars and

workshops have been conducted on the importance of TWAMS and the necessity of enlisting farmers' participation in irrigation management. What has brought about this change?

Glaring failures daunt the irrigation scenario of our country. The gap between irrigation potential created and irrigation facilities actually utilized has been widening causing great concern. A large centralized bureaucracy is just not able to deliver water where and when the farmer wants, or the amount he wants. Costs have been skyrocketing defying inflation rates. When viewed in the context of dismal returns, irrigation departments seem to be doomed to heavy losses in perpetuity. Naturally government has been forced to think how and where to shift its burden.

How to make farmers pay for the irrigation services rendered by the government is one of the main concerns of the government. Gross under-utilization of irrigation potential and inefficiency and corruption in the government have also pushed the government towards listening to farmers'voices, to enlisting their cooperation. Creation of fresh irrigation potential has become prohibitively expensive so that government has turned toward. reviving/modernising TWAMS. Here the fixed assets have already been created; the only expenditure is to restore them to reasonable levels of efficiency. There is also a growing awareness that such a huge machinery as irrigation cannot be run without the active involvement/cooperation of the users. How to transform the users into partners and collaborators with an adequate sense of rights and responsibilities is the greatest challenge before the government today.

Pilot experiments in turning over parts of large irrigation systems or whole of small ones to the farmers to manage are being conducted throughout the country with the help of voluntary organizations and universities. Appropriate legislation and areas of interface between the government and farmers are being discussed actively. How to motivate the farmers, what package of incentives to offer, who should be catalysts are all subjects of much discussion today.

Revival/modernization of TWAMS

Since indigenous systems of irrigation and water management were highly localized one comes across as many patterns of management as there are irrigation sources. The great variety of norms and rules make it quite difficult to develop prototypes. In fact a high degree of flexibility and freedom in the formation and execution of rules and norms is both desirable and necessary for the effective functioning of irrigation management, for irrigation as we mentioned earlier is a matter of micro adjustments between soil, seasons water availability and crops.

Secondly, studies of traditional irrigation management patterns are still in a nascent state and there is more to be done before we can pull out even concepts and philosophies, much less, working models.

Thirdly, agriculture and irrigation scenario have changed so much that it is impossible to go back to traditional systems of management without radical modification. What precisely these modifications should be are not easy to decide since in-

terests of all kinds are at work at the local level which try to mould the organization in their own favour.

In spite of these difficulties, revival of TWAMS, local planning and management of water resources, integration of local plans with watershed development planning are very much the need of the day and sooner we address ourselves to these problems, the better the chances of meaningful achievements in irrigation development.

Some of the well known and successful experiments of revival of modernization of TWAMS are: Pani Panchayat in Maharashtra, Sukhomajri Chandigarh, revival of construction of johads in Alwar district Rajasthan by Tarun Bharat Sangh, rehabilitation of tanks in TN with farmers' participation by Anna university, Ford Foundation and World Bank, etc. But these experiments are far too few to start off and to establish a tradition. We need to put in much more efforts and energy into joint management of water resources by government and people.

World water crisis and relevance of TWAMS

As environmental problems engulf the world, water is an area in which they are acutely reflected. Industrialisation has brought in its wake severe problems of water pollution. Water needed to cleanse rivers of industrial pollutants may be more than water needed to produce industrial products. We in our country cannot blindly imitate this pattern of industrialization with its concomitant levels of pollution. We have a much larger population for whom we have to provide water for drinking and other domestic needs, and for whom we have to

grow food. Irrigation occupies already 80% of our water consumption. We simply cannot afford to pollute our rivers and tanks.

In fact water crisis has already hit us in a big way. Indiscriminate proliferation of tube wells borewells, has led to rapid lowering of ground water table. We are using up reserves of ground water built up over several centuries. This has especially reached crisis proportions in coastal areas (where sea water intrusion is becoming a reality) and in hard rock regions (where water table has rapidly gone down to depths of several hundred feet in the past few years). In canal irrigated areas waterlogging and salinity are claiming more and more land. The cost of creating surface irrigation potential has reached a formidable figures and cannot even be conceived of without massive foreign capital inflows, while utilization of created potential remains as low as 40 to 50%, if not less. Deforestration has increased our proneness to both droughts and floods. Drinking water is becoming a problem everywhere. In the meantime people displaced by major irrigation projects are voicing their protests in a determined manner. In tackling all these problems perhaps our traditional water management systems may teach us a few lessons. Perhaps we need to decentralise our water resource planning; to develop local watersheds; to revive our old practices of community cooperation and maintenance; to revive feelings of reverence towards water sources. We may have a lot to learn from our traditional water management systems for our very survival.

Part II

Engineering Practices

Introduction

The art or science of water management is considered to be the activity to reduce non-average events of drought and flood. In the Indian subcontinent water availability in the form of precipitation is highly erratic, unpredictable and varies widely from region to region. In the dry regions of Rajasthan water scarcity is a perennial reality, whereas in the humid tropics of Kerala natural bounty is in the form of flood. In the response to vagaries of nature water management practices in the dry region consist of conserving every drop of water, while it is removal of excess water in wet regions. The variety and complexity of management practices is strikingly manifested when there is need of excess water removal in wet season and need of storage for dry season.

In this context a wide variety of indigenous techniques suited to the local climate and topographical characteristics have been developed in India, or, for that matter, in many parts of the world where availability of water is a key factor for bio-activity. The famous systems of Karez in Baluchistan and Negev in Isarel are two among many examples. In India

also these techniques have been evolved through millenia's work. The present effort is an attempt to understand the engineering aspects of these systems in their respective ecological niches, with a view to effectively use for revival and modernisation efforts. The purpose is also to draw the attention of modern engineers towards technological diversity of the systems, whereas modern practice is to apply uniform technological model irrepective of regions' characteristics.

The diagrams included in this part are representative illustrations and do not replicate actual landscape. The effort is to visually present the system described on the basis of written script. All the shortcomings are solely authors' responsibility.

Storing Water

India is a monsoon country where rain fall occurs within a few months of the year. Storing water is therefore essential. Methods and use of storage, however, vary widely depending upon the local geography and climate. It can be on-surface or sub- surface storage. In this chapter we shall deal with some of the storage techniques which have been important means of water management.

The main purpose of storage works is to preserve water for subsequent necessities such as,

i) drinking water supply for humans and animals;

ii) irrigation;

iii) religious purposes.

These storage works also contribute to conserve water and soil.

Nadi, Tanka, Bowari, Jhalara, Pokhar .... are different local names of storage works meant for conserving water for drinking purpose. While some of them are created solely to satisfy

human needs, majority of them meet the requirements of both animals and humans.

Eri, Cheruvu, Kalvai, Kunta, Ahar, Pokhar, Beel, ... are all storage works meant for irrigation spread in the length and breadth of the country and play an important role in the region's agriculture. The total net area irrigated by storage works at present is estimated at 3.6 million hectares. Apart from direct benefit of irrigation, they also contribute to soil and water conservation. Nearly 25 million hectares of land is estimated to be under the influence of these storage works in the form of catchment, submergence and command area.

Although all storage works indirectly improve soil moisture and induce deep percolation to ground water table, some of them like *Khadin* in Rajasthan, *Bundhies* in Madhya Pradesh are exclusively for increasing moisture in soil profile. Whereas, *Rapats* in Rajasthan is a structure which induces ground water recharge. Although the government land use statistics do not include them as area under irrigation, it is felt that approximately 0.3 million hectares of area is served by storage works meant for soil moisture improvement.

All these storage works, though perform similar function, have wide variation in design and subsequent use pattern. Let us try to understand what makes these broadly similar structures different. We limit our discussion in this chapter to irrigation storage works and deal with storage works for drinking water supply in the next chapter.

Irrigation water is conveyed to the land by two methods.

i) under the force of gravity, which is known as 'flow irrigation'; and,

ii) lifting of water through different devices, which is known as 'lift irrigation'.

Further there are three main classes of irrigation systems.

i) **Tank and pond irrigation systems**, wherein the water required for irrigation is supplied in accordance with crop requirements as per the availability of water. The storage works in this type may be of two kinds.

Above surface type storage works, where reservoir is created above the surface of terrain to provide gravity irrigation. Tanks in Southern India known by different names as *Keri, Eri, Cheruvu, Kalvai, Kunta,* and tanks known as *Ahar* in Bihar are important variations in this category.

Below surface type storage works, which are dug out ponds and necessitate lifting before gravity irrigation. *Pokhar, Talab, Jhil, Beel, Sagar* are important variations in this category.

ii) **Inundation irrigation systems**, is carried on through deep flooding and saturation of the land to be cultivated, which is drained off before planting of crops. Supplemented by natural rainfall the moisture stored in soil by inundation serve the purpose of cultivation. It is also termed as 'flood irrigation'. These structures are primarily *above surface type*. In Indian literature such storage works are called 'submergence tanks'. Important variations in this type are *Khadin* and *Johad* in Rajasthan, and *Bundhies* in Madhya Pradesh.

iii) **In situ storage**. In this category storage structures are created to retain the precipitation and to help it infiltrate the soil. The difference between inundation irrigation and in situ storage is the method of cultivation. In inundation irrigation cultivation fol-

lows submergence, whereas in *in situ* storage they occur simultaneously.

Many of the above mentioned systems are more commonly known as **tanks**. We now focus on design variations of tank technique.

1. The Tank Technique

Tank can be defined as a technology for the conservation and utilization of runoff water for irrigation.

These structures served dual purpose of soil conservation by holding back the runoff water at numerous points in watershed, and irrigationby redistributing stored water under gravity.

In order to stop the flow and create a small water reservoir an earthen embankment is erected across the flow of water. Such embankment is curved in shape and between two rising grounds in a concave form. Both the ends of embankment loose the height gradually because of the land gradient while water is retained in the belly of curve.

1.1 Use Pattern

Tank in South India (Fig. 1) is a reservoir to store runoff water, which is drawn and directed through channels to irrigate the plots at lower level under gravity. While in past the tankbed seems to be cultivated regularly, in present it is cultivated in exceptionally dry season only.

In the case of *Ahar* it is a mixed practice. The *Aharbed* is cultivated regularly in dry region (Fig. 2), whereas *Ahars* located in relatively wet areas are simple gravity irrigation tanks. In

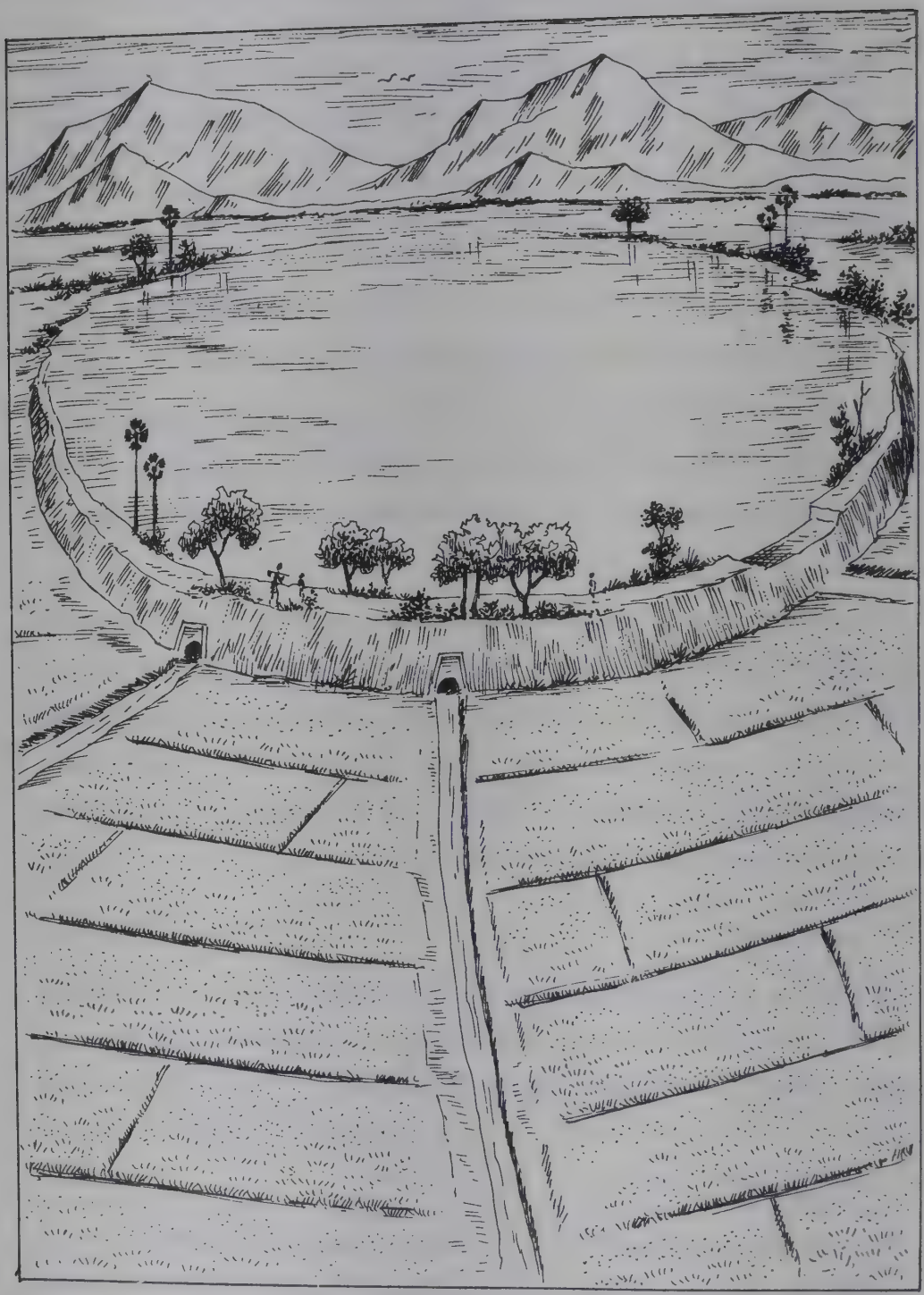

Fig. 1

Fig. 2

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Fig. 3

the former case harvested water is utilized for protective Kharif irrigation in command and not retained perennially. Water in the submergence area of *Ahar* is drained off or pumped to higher lands for pre-harvest or pre-sowing irrigation and the bed is cultivated for Rabi crop. Hence in this case the command, submergence bed and also part of the catchment are cultivated.

A *Khadin* system consists of two segments: a cultivated area and the catchment area (Fig. 3). Soon after the first rains Millet, a rainfed crop, is sown. If the rainfall is good after the harvest of Millet water is allowed to percolate and by early November winter crop is sown. If water persists even after early November, it is removed by means of sluice.

Bundhies consists of embankments with height neither as great as the Ahar and the South Indian tanks, nor as low as the field boundaries. Because the land slope is gradual, large area gets submerged. In case of surplus water to be drained out Waste Weir is provided. The sluice gates are provided at the deepest point to drain out the water. After the rain water is drained out the tankbed is cultivated. In the case of submergence tanks the soil retains moisture for a long time and it is possible to raise a good winter crop without irrigation (Fig. 4).

The simplest method of *in situ* storage is suitable to level surfaces. The fields are embanked on all sides or from three sides. The embankment holds up the drain water. Water is subsequently drained off a fortnight before sowing.

Many of the tanks are interlinked and create an integrated design. The tank at heigher level release its surplus water as runoff to a tank at a lower level. This in turn may release its

Fig. 4

supply to another located further down slope. A gravity irrigation tank with an independent catchment is called an isolated tank. Whereas a series of tanks having common upper catchment area are known as chain tanks (Fig. 5). When tanks are fed by canals taking water from a river they are called the system tanks of that river (Fig. 6). Chain tanks are generally found in the upper catchment area of watershed. System tanks are confined to lower or middle plains of the rivers.

1.2 Size Variation of Tanks

The South Indian tanks are classified on the basis of irrigation capability of command area. They could be classified into three categories: 'minor', i.e., having a command area of less than 50 acres; 'medium', i.e., command area is between 50 and 100 acres; and, 'major', i.e., having a command area of more than 100 acres. Tanks which irrigate more than 500 acres are called 'big tanks' or 'terminal tanks', which may be referred to as reservoirs.

On the other hand, *Ahars* are classified on the basis of the area of submergence. Most *Ahars* flood less than 500 hectares, while others flood as much as 4000 hectares. *Ahars* are often built in series. The overflow from one *Ahar* is trapped by second *Ahar* further downslope. In such case catchment of the second *Ahar* becomes command for the first *Ahar*.

Bundhies or submergence tanks are generally constructed in series and they appropriate every drop of runoff water, wherein the surplus from one *Bundhie* is trapped by another *Bundhie* in series. Hence it is difficult to specify the exact size of a *Bundhie*. However, 0.3 million hectare, it is felt, have been irrigated by this system.

Fig. 5

Fig. 6

2. Components of tank

The following are the important elements of individual tank technique:

i. *Catchment Area*, the area from which runoff water is collected;

ii. *Submergence Area*, the area under the stored water;

iii. *Bund*, to retain water and withstand water pressure;

iv. *Waste Weir*, to drain-off surplus water;

v. *Sluice*, To redistribute and regulate water drawn for irrigation;

vi. *Sluice location indicator*,

vii. *Distribution System*, to convey water to command area; and

viii. *Command Area*, the area cultivated by stored water.

2.1 Catchment Area

The volume of inflow of water into a tank depends on the amount of rainfall and the runoff potential of the catchment area. A rough estimate of ratio of storage area to catchment area in Andhra, Bihar and Tamilnadu is of the order of 1 : 3.5. In the case of steeper slopes *Ahars* have substantial catchment area, as ratio of submergence to catchment is lower. But in areas where the land slopes gently, owing to the cultivation of catchment area, the ratio is high. The diversion channels called *Pynes* that link *Ahar* with nearby hill ranges or drainage stream extend the catchment of *Ahars* to increase the potential of runoff water storage.

For *Khadins* catchment area and submergence area form an integrated whole to ensure sufficient runoff. A rocky catch-

ment in the vicinity of *Khadin* is a prerequisite. Roughly the submergence to catchment area ration is 1 : 10 to 1 : 15.

According to one calculation about 220 mm of rainfall being harvested at a rate of 25 per cent runoff will induce 550 cubic meter of runoff per hectare (one mm of runoff equals 10 cubic meter of water per hectare). For the submergence to catchment area ratio to be 1 : 2, 1100 cubic meter will be harvested from catchment per hectare of land under *Khadin* plus 550 cubic meter harvested on *Khadin* land itself. Even if 50 per cent of it were to evaporate the remaining quantum of 825 cubic meters per hectare will be sufficient to raise crops.

2.1.1 Artificial treatment of Catchment

Many methods have been developed over centuries. The aim of catchment treatment is to render the soil surface impermeable. This eleminates infilteration and more runoff is achieved.

Following is the list of catchment area treatment

1. Cleaning sloping surfaces off loose material;
2. Improving vegetation management by planting different species or by cropping;
3. Mechanical treatment of the soil, like smoothening and compacting the surface;
4. Making surface hard by using for example, sodium carbonate, i.e. Dhobi soda;
5. Reducing soil permeability by application of materials like cement, mud, tank silt + wheat husk, lime concrete, tank silt + mud + asphalt;
6. Covering the catchment with flexible/plastic material.

The importance of the technique is felt in the desert of western Rajasthan, particularly in drinking water scarcity districts of Barmer, Bikaner and Jaisalmer where soils are having high rate of infilteration. In this regard, the water harvesting method of *Negev* desert is an interesting example. Some 4000 years ago thousands of small terraced farms were cultivated. Runoff water was collected from the catchment area 20 to 30 times larger than fields. These systems involved clearing hillsides which serve the purpose of catchment to smoothen the soil and increase run off and then building contour ditches to collect the water and carry it to low fields to irrigate crops. All the loose surface stones in the catchment area were collected putting great effort and were heaped into mounds. Runoff was increased for three reasons, first, water was prevented to enter in to ground, second, rate of runoff was increased and hence evaporation was decreased, third, vegetation cover was reduced, hence increase in runoff. At present Israel has adopted same method to cultivate otherwise desert area with only 24 to 100 mm of average annual rainfall.

2.2 Submergence Area

The physical and chemical properties of soils under the submergence area of tanks needs to be investigated. In the case of *Khadins*, where the tankbed is cultivated, the submergence area itself is command area. In contrast to the course textured sandy soil in surrounding area, soil under *Khadin* is mainly of sedimentary origin, fine textured, young and recent origin. The data on soil profile indicate that clay content on surface layer is medium to high which improves moisture retention capacity of soil. *Khadin* soil also has fairly high amount of organic carb-

on and nitrogen content, variable cation exchange capacity within the profile, high amount of available phosphate and potash which make them potentially fertile, hence crops grown in *Khadin* are not provided any fertilizers. It is believed that long period for which soils are moist promote chemical weathering and encourage development of high microbial population. As a result they contain more humus and are more fertile than desert soil.

2.3 Bund

The bund is a physical structure that withholds the water (Fig. 7).

The size and shape of bund differ according to the type of soil, topography and location of the tank in watershed.

Shape of Bund: A curved, semi-circular, irregular shape is common in South India, provided to ease the water pressure (Fig. 8). The tanks in the upper reaches of watershed being small in size and shallow consist straight but curved bunds at its extremes. In the middle reaches the tanks are horse-shoe shaped to distribute the force of standing water. The shape of the bund near the coastal plains is usually curved, which may be repeated many times.

The bund follows the contours as far as possible in the case of *Ahars*. When it is desired to terminate the bund it is turned transverse to the contours to meet higher ground.

The site of the *Khadin* is selected in a way that only one side bund is needed which is generally straight in shape.

Fig. 7

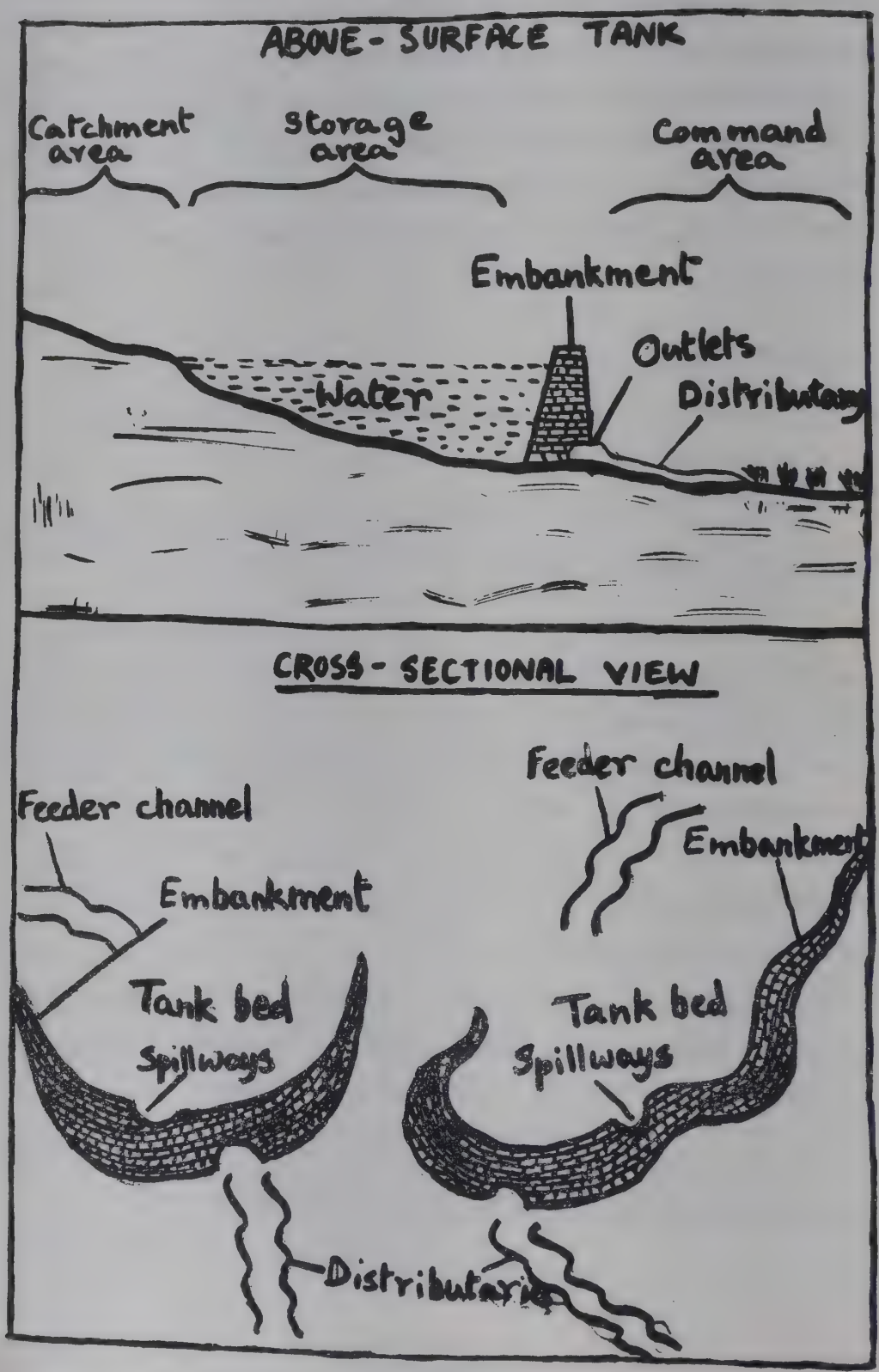

ABOVE - SURFACE TANK
Catchment area
Storage area
Command area
Embankment
Outlets
Water
Distributary
CROSS - SECTIONAL VIEW
Feeder channel
Embankment
Tank bed
Spillways
Feeder channel
Embankment
Tank bed
Spillways
Distributaries

Fig. 8

2.4 Depth of Maximum Impoundment

The general runoff tanks in South India have a maximum depth of less than 15 feet, while some are as deep as 25 to 30 feet. In a few exceptional cases the maximum depth of water exceeds 35 feet.

In the case of *Ahars* the water retaining bund is usually not more than 27 feet height and extend upto several kilometers. The maximum depth of impoundment in this case is between 6 to 7 ft.

Khadin bund is usually 4 to 10 feet deep. In exceptional cases the depth goes upto 15 feet. Length of the bund is usually between 300 to 500 meters. The depth of impoundment is corresponding to the depth of the bund with a free board of 1 to 2 feet.

In the case of *Bundhies* the height of bund is about 6 feet, whereas in the case of in situ storage the bund's height is 1 to 1.5 feet. *Bundhies* hold water about one meter deep when the fields are full.

2.5 Physical Layout of Bund

Bunds are generally checkdams of trapezoidal section, made of homogeneous material throughout the cross section, wherein the soil used for the bund is the same throughout the section. In few cases a bund with an impervious core of clay or in exceptional cases masonry may be provided.

To guard against slipping both the faces of the bund are provided with slope. The outer (downstream) slope is somewhat steeper as it would not become saturated with water.

The inner (upstream) slope has to take moisture but the slope receives much support from the water pressure and it is also provided with stone revetment. Depending upon the quantum of the water stored and type of the soil used, slopes of the bund vary from 1.5 horizontal to 1 vertical for small tanks with water depths not exceeding 8 feed to 2 horizontal to 1 vertical in larger ones up to about 16 feet.

The water faces of tank bunds are usually protected from erosion by rough stone revetment which is carried from end to end of the bund. In many cases, however, revetment is only provided in the length of the place where the water spread is widest or the bund must be exposed to wave action. The thickness and length of the revetment decided in each case on its merits. But it is common to revet with 1.5 feet thickness of rough stone packed over 6 inches thick of broken stone.

Generally the top of the revetment is carried to one feet above maximum water level of a tank but in important tanks or in very exposed situations revetment should be carried up to the top of the slopes.

The general dimensions of bunds of small and medium size tanks in South India are as follows.

Table 1

Depth of deepbed below full tank level in feet	Height of top of bund above maximum water level in feet	Width of top of the bund in feet
5 to 10	3	4
10 to 15	4	5
15 to 20	5	6
over 20	6	9

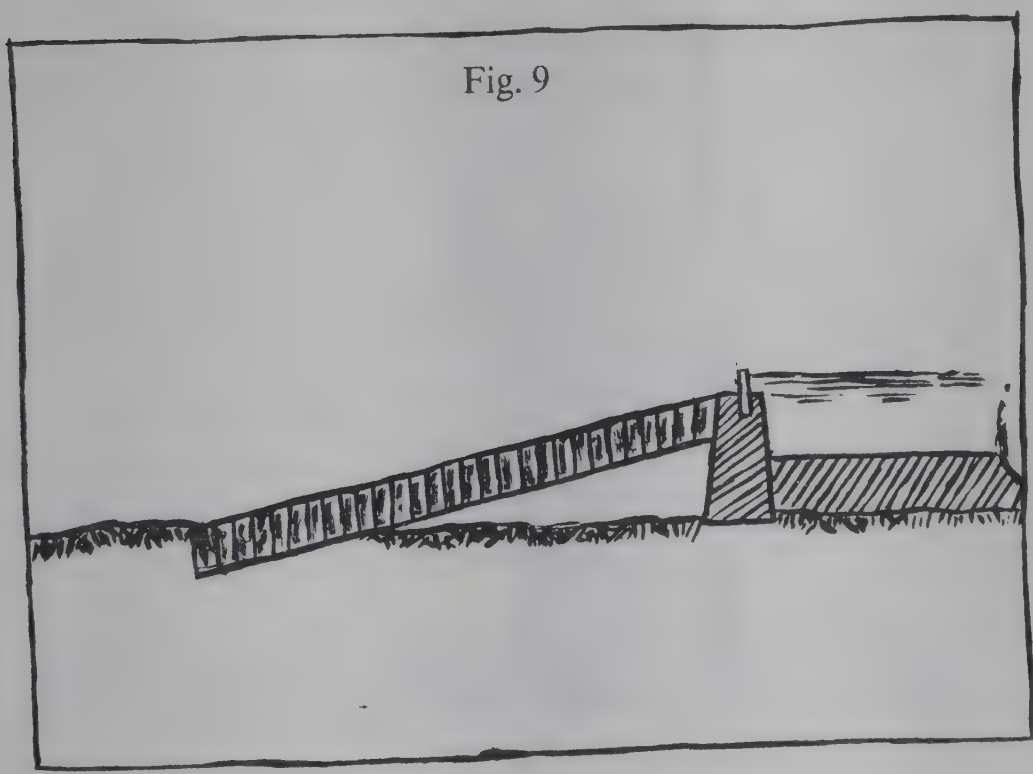
2.6 Waste Weir

Waste weir is provided to discharge the surplus water without causing any damage to the bund. A weir is a portion of a dam (bund in this case) over the crest of which surplus water is discharged (Fig. 9 and Fig. 10). A waste weir is generally at or near one end of the bund from where the fall of ground finds its way into the nearest stream or water course. If tanks are constructed in a series, surplus water from a weir is led to next tank in the chain. Waste weirs can be classified broadly into two types: i) Flank Weir; ii) Flush Escape.

2.6.1 Flank Weir

It is provided as a part of the bund, generally at an extreme end. Main features of such weir are the following.

Fig. 9



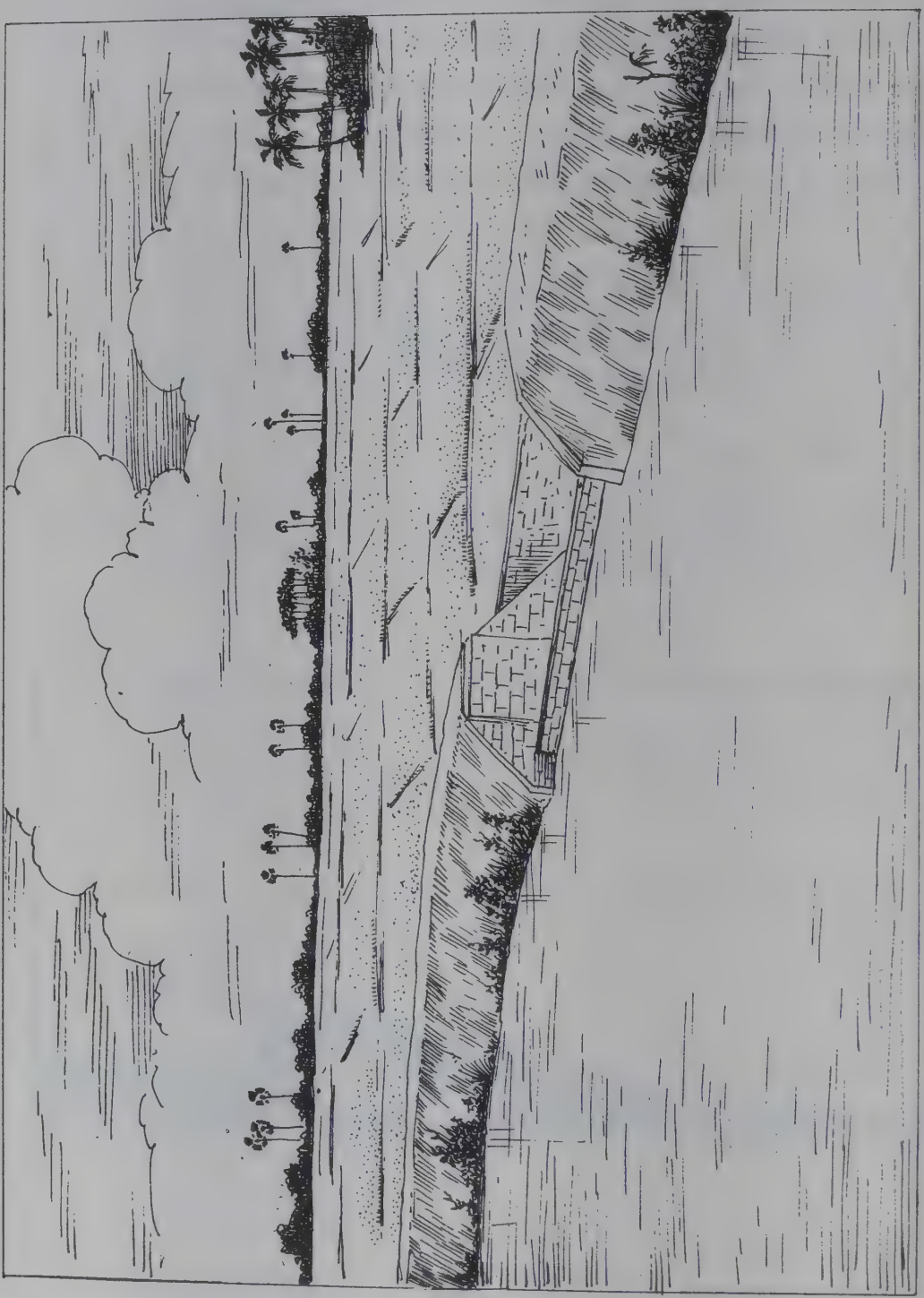


Fig. 10

Crest Wall, which is a portion of the bund (dam) over which water is discharged.

Apron, masonry or hard rock structure receiving overfall water. This could be further classified into four types: Horizontal Masonry; Sloping Masonry; Sloping Rough Stones; and, Steeped Apron.

Length and height of the weir are so that the quantity of water estimated as the maximum flood discharge likely to enter the reservoir can be disposed off. The effective storage capacity of tank is limited by full tank level (FTL) but the area submerged by the tank water spread and height of the bund and revetment are dependent upon maximum water level(MWL). So the difference between FTL and MWL should be disposed off to ensure safety of the bund. The length of the weir is decided on the basis of the quantum of the water required to be discharged. In small and medium sized tanks the usual difference between MWL and FTL is from 1 feet to 2 feet and it is rare to exceed 3 feet.

2.6.2 Flush Escape

A flush escape of sufficient width may be constructed at either flank of the tank or elsewhere along the perimeter of the watershed contour. The natural ground surface is at full tank level and the ground falls away from this giving a suitable surplus escape channel.

2.7 Sluice

Sluice consists of a culvert or pipe running through or under the bund to convey water from the tank to the distribution canal, which may have a wall or tower head at or where

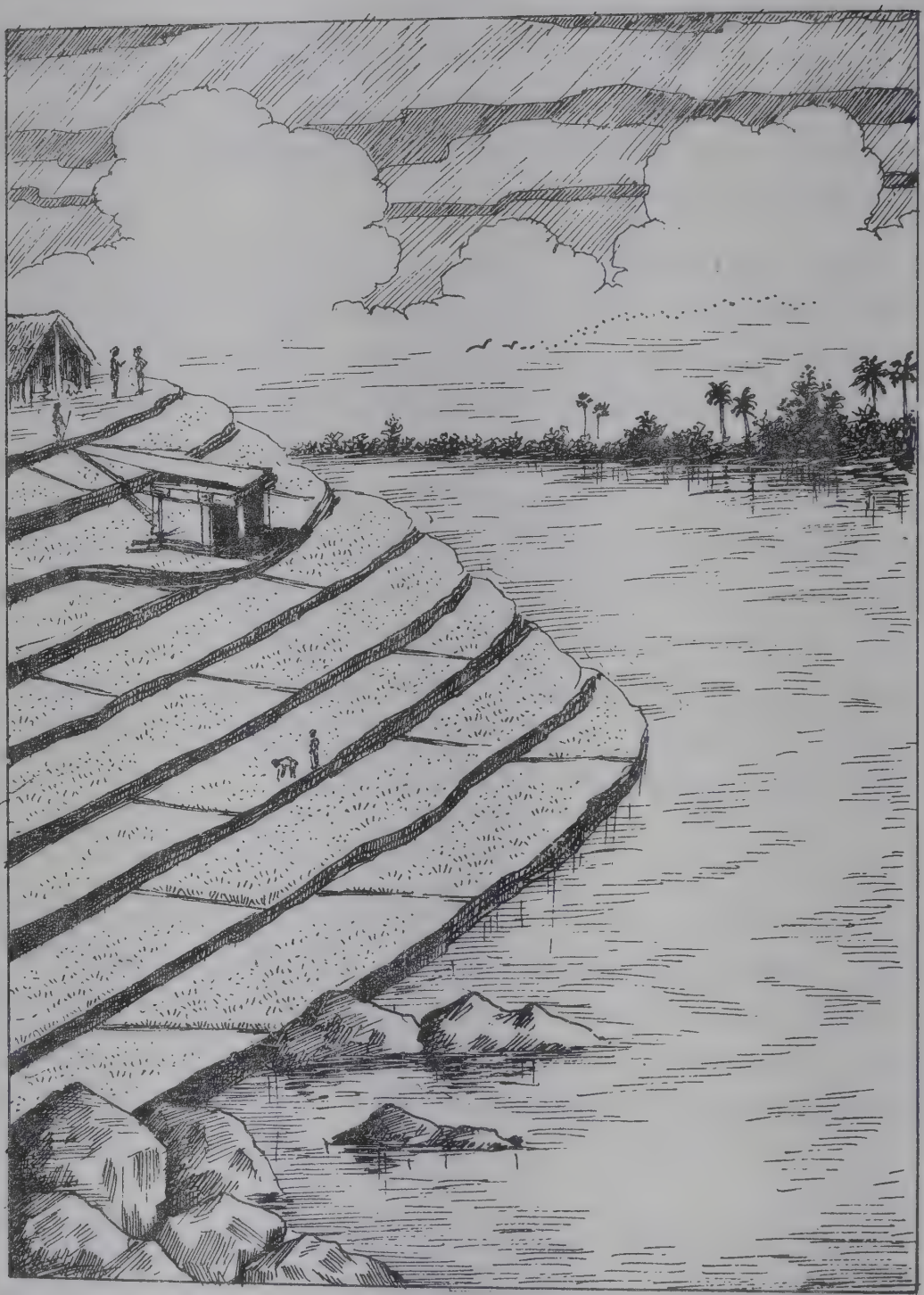


Fig. 11

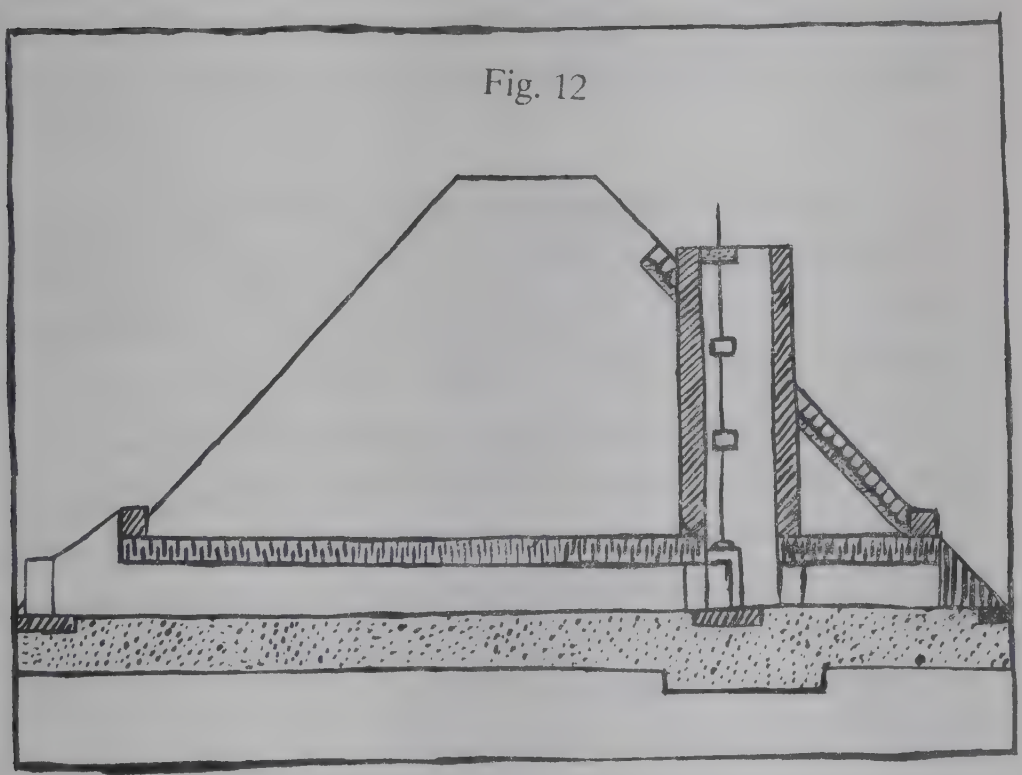
the upstream end on which regulating arrangements are installed. Each tank is provided with sluice/s to provide sufficient water for irrigation (Fig 11 & Fig 12).

Sluices are of two types.

i) For very small sluices pipes either of earthenware, cement or cast iron are used. Sluices consisting of such pipes are called 'pipe sluices'. It is not desirable to use pipes in parts of bunds exceeding 8 feet depth below full tank level as in the case of fracture or leakage examination cannot be carried out without cutting open the bund.

ii) In such cases culverts made of masonry, stone or concrete is provided. The size of this culvert is proportioned to the maximum quantity of water required to convey but in no case should be less than 2 feet wide and 2.5 feet high so as to allow a man to enter for examination.

Fig. 12



2.7.1 Regulating Methods of Tank Sluices

To control inflow of water into the sluice originally 'plug-pole' method was employed. More recently this system is increasingly being replaced by 'shutter' system.

In the plug-pole system the vents used are circular in shape of suitable size in a horizontal stone and the area of opening is regulated by a long caned plug, the wider end of which is of the same diameter as vent. The plug made of wood is fixed to one end of an iron pole. As the plug is raised gradually the vent is opened accordingly, and finally, when the plug is raised completely, the full discharge is obtained.

When plug holes would exceed 8 to 10 inches in diameter two or more holes and plugs are provided in the plug-platform stone. Whereas for deep sluices over 25 feet depth, two or more plug stones at different levels each with separate plugholes is easy to regulate. The upper platform is used when the water is high and the lower one when water level in tank is low.

The plug-pole technique is simple, economical, for very little amount of water is wasted through leakage. The technique is also flexible as the regulating pattern can be adjusted easily according to the varying conditions of water level.

In the shutter system the entry of water into sluice is regulated by placing a sheet of iron sliding over on frame. This shutter is regulated at the top of the sluice by a screw mechanism. Flat shutters are recommended when large quantity of water is to be passed through. Hence they are generally used for heads of over 30 feet.

The sluice outlet is generally covered with masonry archwork of stone, brick or concrete type.

2.7.2 Sluice Location Indicator

In each tank one stambh is located in the middle of the bed in line with sluice. As the process of siltation continues the stambh indicats the location of sluice and also quantum of silt being accumulated.

2.8 Distribution System

Canals and channels are the distribution works of a system whereby irrigation water is conveyed from the head works to the fields. 'Main canals' get their supply directly from the head works, while the 'branch canals' or 'distributaries' draw from the main canals. 'Field channels' are narrow channels constructed by cultivators to convey and distribute water to individual fields.

2.8.1 Different Methods of Alignment of Irrigation Channels

Irrigation channels are generally aligned with reference to the contour of the country. A contour channel is carried on an alignment to conform the contours of the country and necessary slope is given along the length to produce the required velocity of flow. As the line of flow of surface drainage is at right angles to the ground contours such a channel cuts across the natural drainage lines of the country. A watershed channel is aligned along natural watershed ridge, hence there will be no drainage along such a line. A side slope channel is one aligned at right angles to the contours and not on a watershed

or valley line. Such a line would be parallel of natural drainage line.

As a rule the upper parts of main canals are aligned as contour canals. In the case of direct flow systems the first reach of main canals is kept deep in cutting that no land can be commanded. It is carried upto the point where it commences to command the land is continued as contour canal proper.

Branch canals and distributary channels take off from a contour canal from where the contour canal crosses watershed. They are aligned as watershed channels upto the adjacent drainages from where subsidiary channels offtake to cover the whole area to be irrigated.

The major canals, being the receivers of water directly from the tank, have to withstand the high velocity of discharge. To reduce the velocity entering the main canal the outlet provided at downstream of bund is kept at right angle to sluice. In newly constructed tanks this system is absent. In such situation canals inevitably need lining to withstand the velocity.

Accumulation of silt is the major problem and reduces carrying capacity of these canals. But frequent desilting is needed in distributaries as they are planned for flow of water at the low velocity and low quantum of water.

3. Major Problems of Tanks

Siltation, Seepage and evaporation continuously affect the water storage capacity of tanks and hence require due attention.

3.1 Siltation

The storage capacity of a tank decreases, on an average, at a rate of 0.5 per cent a year due to silting.

When the runoff the catchment of a tank is large in comparison to tank capacity there will be surplus water for long period in the tank. In this case considerable portion of lightest silt in suspension is passed off with the surplus water and only lightest kind of silt in suspension will be deposited in the tank-bed. Whereas, when the tank is large in comparison to the annual runoff from the catchment area all the water borne silt carried by runoff water will be deposited in the bed of tank. The heavier silt will be deposited in the periphery area but the fine silt as it takes long time to settle will be spread move evenly all over the tank bed. The thickest deposit will be below the deepest standing water, i.e., in the vicinity of the bund.

The deterioration of tanks by silt deposit is continuous and very serious. Many of the tanks have been impounding silt for centuries and have lost considerable proportion of their capacity. Afforestation and construction of checkdams made of brushwood and stone one suggested to check inflow of silt.

In a few cases pits of various sizes are provided in succession to intercept inflow water and reduce silt load of incoming water in the tank. The chain tanks of South India is an arrangement which result in silting of the upper tanks which are easy to clear being small in size and prevents rapid siltation of lower tanks bigger in size.

The silt accumulated in tank bed is utilised for various purposes. For instance fineness of the silt is suitable for brick making, its impervious character makes it ideal for floor construction and for artificial treatment of catchment.

In this context an interesting study on tank popularly known as Guru Ka Tal located on the bed of natural drain carrying water to Yamuna river, has revealed that sophisticated technology of silt arresting chamber was exising in seventeenth century. The water from the drain used to be directed in a regulated manner towards the silting chamber, which was an octagon of four pairs of opposite sides, surrounded on seven sides by a containing wall of the height that of tanks embankment. On the eighth side running along the embankment were located three sluices. The inner structure of this chamber takes the form of a circular well.

3.2 Loss of Water due to Evaporation and Absorption

The loss of water from tanks vary greatly and is depended upon the nature of the bed. The seepage loss is gradually minimized in the course of tank's operation for some years. Accumulation of fine silt all over the tankbed considerably reduces percolation level.

A practical rule is suggested to calculate loss: through evaporation and leakage combined the quantity reported will be evaporation loss from a free water surface. For all practical purpose seepage losses can be safely ignored unless the tank bed is exceptionally porous.

3.3 Salinity Ingress

Salinization is a serious problem which degrades the soil, affects plant growth and render the soil unfit for cultivation. River and ground water sources contain more salt than rain water and hence the terrain cultivated by them is more salinity prone, whereas rain water helps leaching out of accumulated salt if effective drainage is provided. If the ground water level is in the vicinity of the surface, vertical drainage cannot occur and it can cause considerable concentration. In the case of Southern peninsula considerable gradient of the terrain permit vertical drainage.

In the case of *Ahars* and *Bundhies* further research is required to understand the absence of salinization even though soil has a very poor infiltration rate.

Khadins in Rajasthan has successfully provided irrigation for centuries without serious problem of secondary salinization. There is not much salt accumulation within the *Khadin* whereas a fair amount of salt found accumulated outside the bund. The sediments accumulated inside the *Khadin* gradually raise the bed level. The difference in level between the inside and outside of *Khadin* is found to range from 0.25 to 1.0 meters. This difference in level creates difference in hydrostatic pressure inside and outside when water is standing on the bed and causes greater seepage outside. This allows the salt in the water to be flushed out of *Khadin*.

Water Conveyance

Water is conveyed for irrigation by diverting natural drainage streams. conveyance works may be divided into three types.

i) Conveyance without check in the riverbed (Fig. 1), wherein flood water is drained off through natural diversion; *Kuhls* or *Guls* of Himalayan states, *Dongs*, of North-Eastern states, *Pynes* of Bihar are important variations in this category;

ii) Conveyance with check in the riverbed, wherein the water level is raised in the riverbed by a check and then diverted; *Kulo, Kurambo, Bandhara* are local names of diversion structures. The famous *Anicuts* of South India also fall in this category, wherein the regulation mechanism is provided in the structure itself.

1. Conveyance Without Checks

The bed slopes of valleys of hill streams are generally steep. The diversion channels, known as *Kuhls, Guls* in the Himalayan region and *Dongs, Lowkhongs, Thingels* in the North-Eastern region, serve the purpose of irrigation while

Fig.1

also help reducing the flood damage. In the gentler slopes of Bihar diversion channels are called *Pynes*.

The technique of *Kuhls* consists of contour channels which collect water at higher altitudes following through the hill streams and distribute it to fields located at suitable levels. As the bed slopes of the valleys of hill streams are very steep these diversion channels spread away from the main stream within a short distance from the take off point. Checks are generally not provided on the main stream and hence no control at the head of water channels. The *Kuhl*bed at the head is higher than the riverbed to serve the purpose of flood channel. These channels travel in the winding fashion following the natural contour line which reduces the damage caused by rapid flow.

The channels are usually 10 to 12 inches wide with square or trapezoidal cross section. The length of *Kuhls* depends upon the available discharge in the stream and distance of fields from the source.

In the trapezoidal *Kuhls* percolation losses are minimized with a simple method of lining. Dung is applied at the head of a *Kuhl*, which mixes with water and settles along the *Kuhl*bed. The dung particles block the pores through which the water percolates, thus help increasing the transmission efficiency.

Kuhls are sometimes used in conjunction with storage tank called *zing*. The trickle of the water available at source stream, is not sufficient to allow flow through channel. And most of the water, is likely to be lost as seepage. A small storage is created at the beginning of channel, through which water is supplied in batches.

Pynes are unlined inundation canals work as feeder channels for *Ahars*. In addition to conveying water from a stream, they harvest rain water from the catchment above them. Their bed level at the stream from which they take water is above the normal water level in the stream. This ensures that they take water only when flood level in the stream rises above the bed of the *Pyne*, and do not draw water when there are standing crops in the bed of *Ahar*.

The *Pynes* start from river at an angle in such a way that the water flows down to fields at the lower level. Thus if a river is flowing north the *Pynes* will stretch north-east and north-west. The length of *Pynes* vary considerably. Generally they are long owing to flatness of the gradient. Whereas some of them are simple ditches stretching for a mile or so. Majority of them however are 5 to 10 or even 20 miles long with numerous branches. They are known as *Boklas*,*Terua*,*Karha*,*Sakh* or *Darsakh*.

Besides size and length there are other characteristics which also vary. Some are fed by rough irregular bunds stretched up in the riverbed. Others have well made embankments, often built of masonry, for this purpose. Some *Pynes* contain pukka sluice gates while many have just brickwork opening to let water into the fields. Frequently they travel above the level of the surrounding country and provide gravity irrigation. When they run below the level of land, the water is raised by lifts.

The *Pynes* discharge their surplus water into another riverbed, into *Ahars* or simply end in small channels. The initial lengths of *Pynes* are often filled with silt as flood water

carry considerable quantity of silt. Therefore, *Pynes* necessitate cleaning operation every year after the monsoon.

2. Diversion with Check

The diversion structure, i.e., check dam, created on the riverbed differ extensively in design (Fig 2). A simple method to create temporary structure is to use locally available material like boulders, bamboo, palm trees, banana stems or clay. In the past the Kaveri river and its major branches used to be diverted at different points by such temporary weirs called *Korambo*. However, many such temporary structures have been replaced by permanent masonry structures. There are two major types of permanent structures: i) Barrage known as solid weir; and, ii) Weir.

The barrage is a masonry obstruction in the riverbed. In the north-western part of Maharashtra a series of such structures were created on the river are locally known as *Bandharas*. They raise water level upstream so that the canal can be aligned in higher ground and water from it can flow on to the fields at lower levels by gravity. Within the riverbed the flood water passes simply over the dam structure. Except a few, which are built straight across the stream, majority of them are more or less oblique to the stream course. The shape depends upon availability of hard rock within the riverbed suitable for foundation. The dam walls commonly slope on both the sides to a narrow top. The materials are generally black basalt stone, course concrete mixed with small pieces of bricks. Except a small opening at the middle or at base no provision is made to remove silt.

Fig. 2

The disadvantage of solid weir is that the greater portion of the whole water way is blocked by a solid barrier. The erection of solid weir across a river causes accumulation of silt and rise of river bed causes formation of shoals upstream the structure. And also causes scours of river bed downstream the structure. From this consideration the crest shutters are provided within the weir wall. These shutters are lifted by gear. The advantage of the regulator compared with a solid weir is that it serve the purpose of a weir without greatly obstructing the water way. Weirs across rivers in South India are termed as *Anicuts* being Tamil word for river weir.

Following are the main components of river weir,

i) A canal taking off from one or both sides of the river above the weir.

ii) A head sluice also termed as head regulator to control entry of water in canal. The sill level of the same is arranged at a higher level than the deep bed of river so that, canal is fed with water drawn near the surface which is relatively silt free.

iii) Weir scouring sluices. The function of this sluice is to keep open a suitable water channel to feed the canal and to deepen the river bed in front of head sluice with a view to exclude bed silt from the canal.

iv) Flood banks or other protective works to secure weir from being toppled down by flood water.

There are two important types in this category.

i) Kolhapur type *Bandhara*.

ii) *Anicuts* on Southern India rivers.

2.1 The Kolhapur type Bandhara

The Kolhapur type *Bandhara* consists of a series of stone masonry piers constructed across the bed of the stream. The piers contain grooves to hold shutters. The grooves have a cross section 100 x 100 mm and have a clear spacing of 300 mm. The pier rises to a height of about 4.5 m. above the bed. The width of pier is 1 m., and the clear space between adjacent piers is 2 m.

The shutters being used are of wood in the form of planks about 300 mm wide and 2.2 m. long. When the depth of water in the stream comes down the planks are lowered in to the grooves and the gap between front and back shutters is packed with mixture of straw and mud. Two or three shutters near each bank are left open till all other vents are closed. So that, water level does not rise too high to render the closing operation difficult. This whole exercise takes one to two weeks to complete. This type of shuttering is reasonably leak proof though not completely. The another problem is that wooden planks deteriorate and are needed to be replaced frequently.

The shutters are open during the floods, which passes the weir with only the pier as obstruction. The silt is carried away by the flow. When the flood subsides, the openings are shuttered up and water collects behind the *Bandhara*. This water is pumped to neighbouring fields for irrigation. No canals are built to convey the water, since the quantity of the water is relatively small. The Government of Maharashtra has now standardised the dimension of the piers, vents etc.

2.2 Anicut technology in South India

The famous structure of Grand *Anicut* on Kaveri river at Ullar river is believed to have been constructed in the second century AD. This is also believed to be the oldest hydraulic structure to control flowing river in Indian subcontinent. The excellency of the structure is manifested through its continuation to serve the purpose of flood control till todate. Modern Engineers still wonder how the foundation was secured in the permeable soil of unlimited depth. The foundation base even on date is massive and stable that only superstructure has been improved and modified.

The river regime

The Kaveri, when it enters the delta bifurcates into Kaveri and Coleroon, is wider and large and has been serving as the flood carrier. For 27 km. downstream of this bifurcation the Kaveri and Coleroon run very close to each other and the Kaveri again spills into Coleroon through a short spill course called the Ullar. At this point river Kaveri once again splits into Kaveri and Vennar (Fig. 3), the main irrigation rivers flowing through the delta, which divide and subdivide among themselves forming as many as 36 streams totaling to a length of 1600 kms.

With the passage of time the river courses were getting silted up. The Splitting regime of river course brought in uncertainity in flow distribution. The crucial situation should have arisen long before in the past when the flood flows carried by the Kaveri arm, found their way to Coleroon through Ullar, leaving various rivers and channels in delta dry. A need for structure across the Ullar to raise the water level to gain

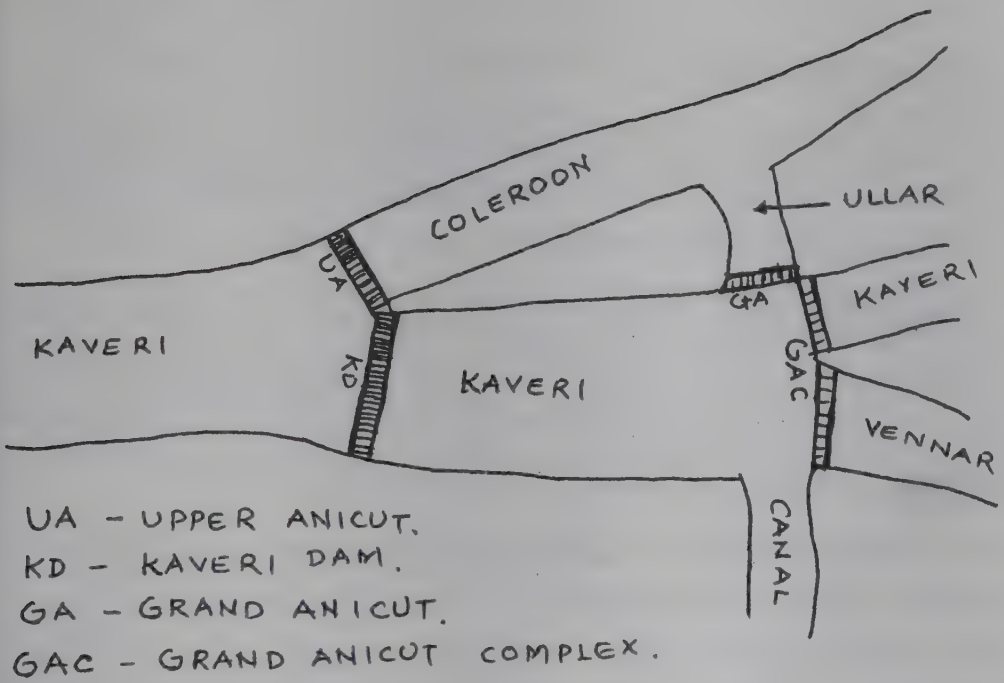


Fig. 3

command for flow through the delta was felt. Thus came the Grand *Anicut* to be built on Kaveri at the Ullar head in the second century AD. The main function of this *Anicut* was to retain the supply in Kaveri and its branches and pass on the surplus into Coleroon through the Ullar river.

The *Anicut* as it is believed consists of a core of rough stores in clay covered with a facing of rough stone in mortar. A portion of the crest was built a curved top and the rest was protected by a rough stone apron. The *Anicut* is 329 m long, 12.20 to 18.30 m wide and 4.57 to 5.49 m high.

Several modifications and improvements were made to the Grand *Anicut* keeping the base structure intact. In 1893 ten undersluices were built by Sir Arthur Cotton in the body wall. In 1886 dam stones were removed, piers and abutments raised and automatic falling shutters were fitted. In 1899 the falling shutters were removed and replaced by lift shutters.

The Grand Anicut complex

Contains the old *Anicut* severally modified, the head regulators for rivers Kaveri and Vennar and for the newly excavated Grand *Anicut* canal.

When the British took over Thanjavur the Coleroon was scouring itself deeper and the Kaveri was getting silted. The silting interfered with the passage of low freshes. Also river became incapable to carry the flood water down.

In 1829, to the upstream of Grand *Anicut* where Kaveri and coleroon splits undersluices were constructed in the Kaveri with outlet into Coleroon to prevent accumulation of silt in the upper reaches of Kaveri. The problem of silting of Kaveri could not be overcome by this work and with the purpose of eliminating this problem Sir Arthur Cotton constructed the upper *Anicut* across the Coleroon arm at the spot where Kaveri and Coleroon splits. This work was designed to prevent too much water flow into Coleroon. It was a plain *Anicut* with a body wall and the usual aprons.

The construction of soild *Anicut* across the Coleroon Kaveri with its open head took a lower portion of flood with high amount of sand with the effect of scouring ot the bed. To obviate this difficulty in 1845 the Kaveri dam was built across Kaveri in line with upper *Anicut* on Coleroon.

While the upper *Anicut*, kaveri dam and Grand *Anicut* ensured adequate flows being carried by Kaveri and Vennar for the delta irrigations there was no means of avoiding flood waters rushing into delta in unrestricted large quantities. The head regulators for both Kaveri and Vennar about 61 m downstream of Grand *Anicut* and at right angles to the same

were constructed having outlets with ventway to pass all the local floods. So that each section of delta gets its share of floods for inundation irrigation with controlled concentration.

The Kaveri regulator has 14 spans and the Vennar regulator has 11 spans. The floor consisted of concrete apron protected in front and rear by retaining walls taken down into the clayey subsoil below. The foundation concrete was made up of one part Surkhi mortar, two of clean river gravel and three of well burnt broken brick. There are rough stone aprons in front and rear of each regulator resting on sand. In the beginning of the present century the new canal in Kaveri delta called Grand *Anicut* canal has been constructed. The head regulator for the Grand *Anicut* canal is located next to the Vennar regulators. This has six vents each fitted in the radial shutters.

Water Conservation

As the length of dry season increases from region to resion, consentration of every drop of water becomes important water management technique than storage. In the drier tacts of Rajsthan and Ladakh where even the drinking water scarcity is perennial problem, water conservation practices exclusively for drinking water are widespread. However, such systems may be existing in the other parts of the country. Information regarding these techniques is available from the dry regions of Rajasthan and Ladakh. The techniques like *Nadis or Johads, Talab, Tanka, Pokhar, Beel, Jheel*, ..., conserve surface water, where as *Bowari* or *Vav*, *Jhalara* conserve sub-surface water mainly utilized for drinking water supply.

These water conservation techniques are of three types:

i) Roof water collection, where roof-top is the catchment area;

ii) Surface water collection, where runoff water is collected; and,

iii) Sub-surface water collection, where ground water is tapped.

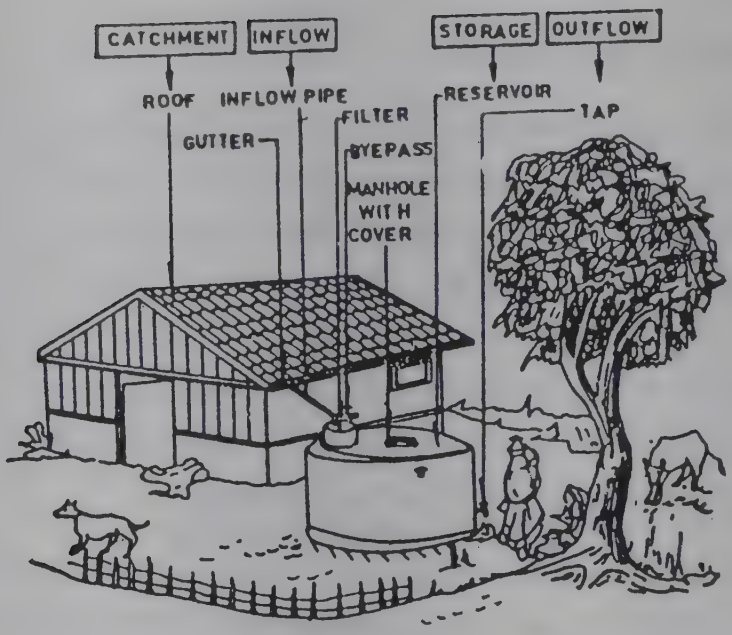
1. Roof Water Collection

Rain water may be harvested in areas having rainfall of considerable intensity, spread over a larger part of the year, for example, Himalayan area, North-Eastern States, the Andaman and Nicobar, Lakshadweep islands and southern parts of Kerala and Tamilnadu. This is an ideal solution of water problem for places where there is inadequate ground water supply and inappropriate surface source. Rain water is bacteriologically pure, free from organic matter and soft.

In this system, only roof-top is the catchment. Appropriate roofing materials are applied to enhance rain water collection. Roof is also given slope and drain is provided along the edge of the roof. It is fixed with a gentle slope towards the down pipe which is meant for free flow of water to the storage tank. Storage tank is generally constructed above the ground to facilitate withdrawal of water (Fig 1). Tank may be made of wood, bamboo, mud or masonry lined with waterproofing material like lime, ash or morum. The size of the tank will depend upon factors such as daily demand, duration of dry spell, catchment area and rainfall.

2. Surface Water Collection

Runoff water is collected in structures known by different names as *Talab, Johad, Dhab, Toba, Talai, Nadi*. Many of these systems were originally meant for irrigation purposes and are now being used for the purpose of drinking water. Further, these general categories are not similar everywhere. For instance, *Nadis* are used for drinking water purpose in Jodhpur, while they are used for irrigation in Ajmer district.



RAIN WATER COLLECTION THROUGH ROOFS

Fig. 1

2.1 Nadis

Nadi or *Johad* is an important source of water for both human and livestock. A *Nadi* is essentially a natural surface depression which receives runoff water from one or more directions (Fig 2). In some instances the *Nadis* are located in such a manner that runoff from the area is collected exclusively in it. Some *Nadis* have stone walls or mud-bund on one or more sides to enhance the capacity of water retention. Location and size of *Nadi* depend on the catchment area it caters. It should be located in areas with lowest elevation to have the benefit of natural drainage and need for minimum excavation of earth. The highest *Nadi* density was observed on rocky

Fig. 2

gravel pediments followed by younger alluvial plains, sandy plains and then sand dunes (Table 2).

Volume of water harvested in *Nadi* per unit of catchment area depends upon size and type of catchment, and amount of rainfall. Volume of water harvested is higher on dunes and sandy plains, when the range of rainfall is between 300 to 350 mm. The volume of water harvested tends to decrease in the higher rainfall ranges due to stabilization of sanduals(Table 3)

Seepage, evaporation and siltation are the major problems that limit optimum utilization of *Nadis*. Evaporation is a function of surface area, whereas seepage is a function of depth of water stored. In *Nadis* loss of water due to evaporation is higher than that of the seepage owing to its large surface area.

Table 2: Effect of Rainfall on Nadi Volume/Catchment Area Ratio Under Different Physiographic Settings

Physiographic Setting	*Nadi* Volume $(m)^3$ per ha of catchment area for various Rainfall figures				
	250-300	300-350	350-400	400-450	450-500
Dune Complex	55.3	110.5	53.0	37.1	-
Sandy Plain	120.4	128.0	131.1	137.3	-
Younger Alluvial Plain	-	-	-	349.9	1066.9
Rocky/Gravel Pediment	491.7	518.9	785.5	1644.7	2264.7

Source : Rainwater Harvesting, Department of Rural development, GOI, 1990.

Table 3: Effect of Ground Slope on Nadi Volume/Catchment Area Ratio Under Different Physiographic Settings

Physiographic Setting	*Nadi* Volume $(m)^3$ per ha of catchment area in Different Slope Groups (% aga)					
	< 1	1 - 2	2 - 3	3 - 4	4 - 5	> 5
Dune Complex	54.3	108.2	45.7	29.0	-	13.8
Sandy Plain	110.6	154.2	121.1	-	-	-
Younger Alluvial Plain	466.4	578.5	731.8	-	-	-
Rocky/Gravel Pediment	51.4	421.5	724.7	945.9	-	1236.5

Source : Rainwater Harvesting, Department of Rural development, GOI, 1990.

The *Nadi*beds, unlike the *Khadin*beds, are generally not cultivated. An important reason is that *Nadi* is essentially a depression. If soils of *Khadins* are compared with that of depression, which also receive sediments, it is found that both the soils are similar in clay and silt content, but differ mainly in sand and calcium carbonate content, which is higher in the soils of depression. The higher content of sand and calcium carbonate is a limiting factor for both plant growth and easy drainage which cause salinity conditions in this soil.

Many of the *Nadis* are interlinked and form a chain. Surplus from one *Nadi* overflows into another *Nadi* below. In some instances the seepage from *Nadis* helps to recharge the soil in *Khadin*.

In recent times *Nadi* water has become highly polluted and causing health hazards mainly due to poor maintenance and

improper utilization. Guineaworm, water hyacinth, mosses and algae are found in large quantity.

2.2 Tanka

Tanka, Kund, Kui are different local names of a covered under ground tank designed to collect rain water from artificial round or square catchment and store it for lean water months. When the tank is constructed with stone or concrete and plastered with cement it is known as *Tanka* (Fig. 3). When it is soil excavated and plastered with lime and ash it is known as *Kui or Kund.* In the case of Kui the bottom is left unpaved and its mouth is covered with a local tree, *Bhida Phog.* Then it is plastered with mud once in six months. *Kuis* are 8 to 10 meter deep and the diameter is about 1.5 metres. Whereas,

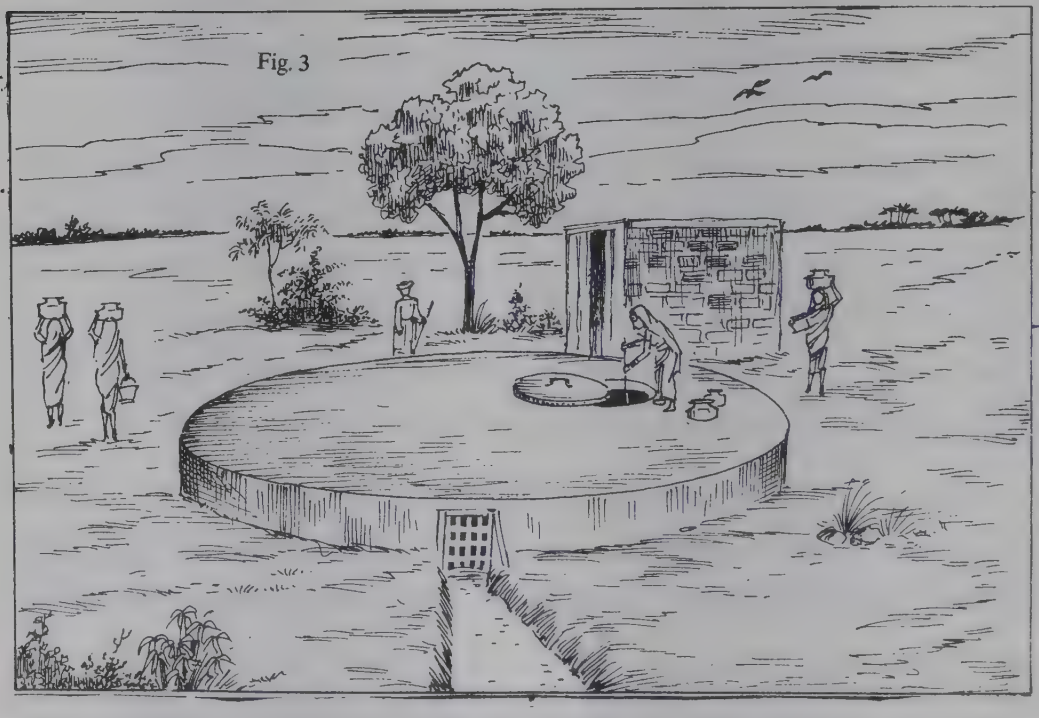


Fig. 3

Tankas are circular in shape having a depth to diameter ratio varying from 3 to 4.22 meters. A *Tanka* of 22 cubic meter capacity for single family of 5 will ensure water supply throughout the year.

The top of all theses structures is closed except for a small opening to draw water with a small rope and bucket. A door is provided to close this opening and protect the water from dust and other things.

The catchment area is called *Paytan*. Generally the area of *Paytan* is 3 to 4 times of the diameter. The catchment is also given slope of 3 to 4 per cent towards the well in the center and is treated with cement or local materials like pond silt, Murrum, wood, coal ash, gravel etc.

After clearing the soil surface of vegetation and giving land a proper slope the pond silt is spread in a three to four cm thick layer in the entire catchment. This layer is compacted and made semi-impervious after the first shower. Sheep and goats are made to move over the surface again and again till the surface is compacted. During this process water is also sprinkled. Wood ash is used to repair the catchment which settles and fills the pores and makes the surface water proof. In the place of pond silt murrum is also some times used.

3. Sub Surface Water Collection

Ground water is bacteriologically safe and does not need purification unless the soil around the place from which water is taken out is polluted. Ground water is predominantly tapped by wells bearing different forms and names.

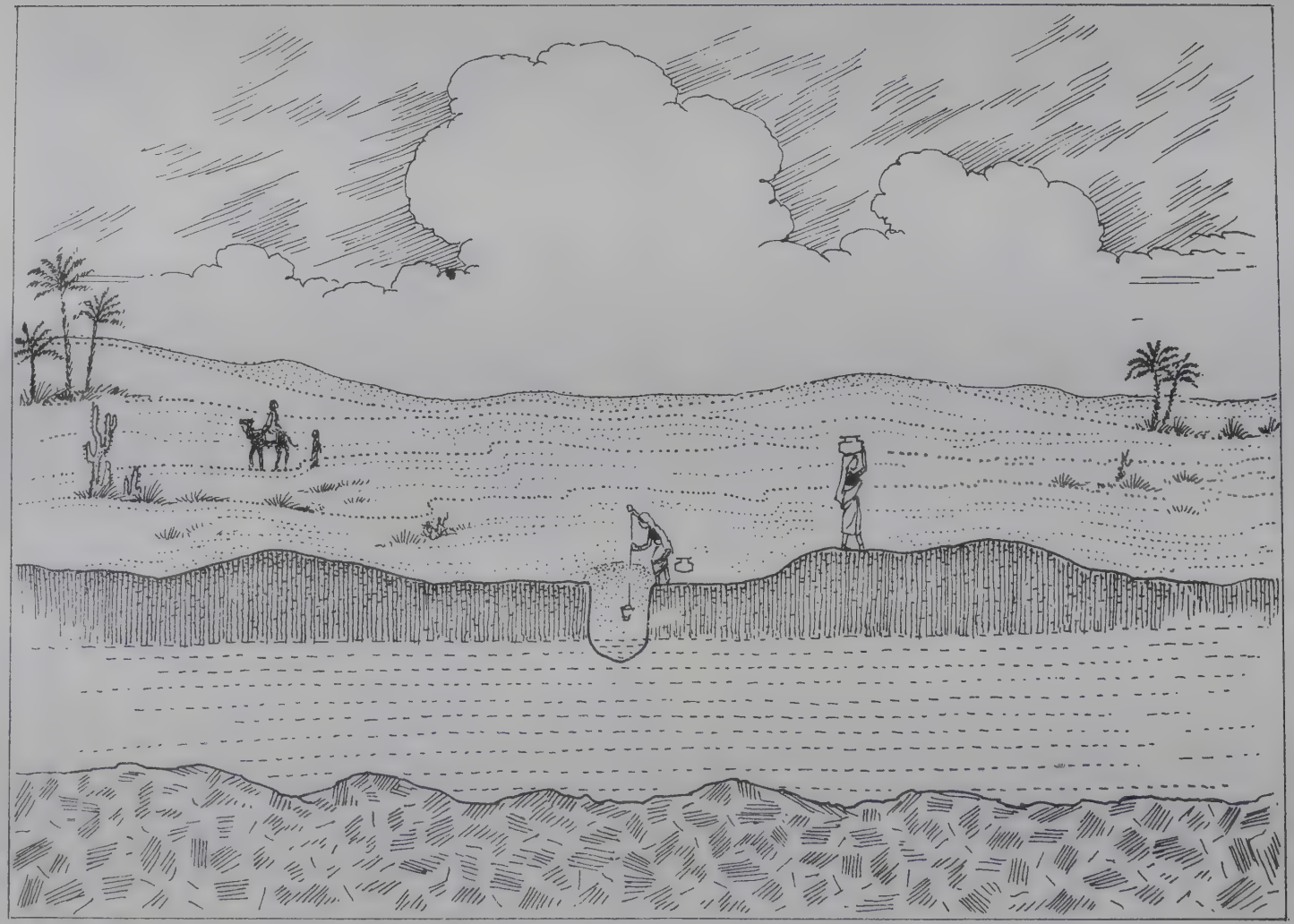


Fig. 4

Paar is a shallow well, dug in a depression with the rocky sub-soil layer near the surface. Water is used only for drinking (Fig. 4).

Kuiyan is a somewhat deeper well with more regular water supply and often covered.

Chua is a well which is dug in a dry riverbed.

Bawari is a community step-well and steps are provided only one side to reach the water (Fig. 5).

Jhalara or *Vav* is a square *Bawari* which has entrance on all the four sides leading to the water.

3.1 Sub Surface Water Conservation

Water can be conserved sub surface as ground water. That reduces evaporation losses considerably. Also due to slow sub surface movement it is available for use throughout the year, in almost all the areas except in the highly permeable soils.

The artificial recharge method comprises increasing the area of infilteration. It is effected by spreading channels and by recharge ponds. Spreading channels or unline canals where water moves at very gentle speed, which effects maximum infilteration. Recharge ponds helps in collecting surface runoff at the places where it can be easily infilterated into sub surface ground water reservoir. This method is useful only for recharge to unconfined aquifer.

Rapats of Rajasthan and percolation tanks of Maharashtra fall under this category. Sandy or rocky soil provides favourable condition for such tanks, since water can quickly percolate underground. The soil suitable to *Rapat* is sandy

Fig. 5

with clay content of 3 to 9 percent. Whearas soil in Maharashtra suitable for percolation tanks is rocky.

A *rapat* or a percolation tank, like an irrigation tank, has a structure to impound rain flowing through a watershed, and a waste weir to dispose of the surplus flow in excess of the storage capacity of the lake created. If the height of the structure is small, the bund may be built of masonry, otherwise earth is used. The Rajasthan *rapats*, being small, are all masonary structures. But no irrigation canals are provided, and hence there are no intake structures or sluices in the bund.

Whearas the bund is made of earth in Maharashtra, the section of the bund is similar to that of an irrigation tank, except that the cut-off trench is taken to a depth equal to half the height of the bund. The purpose of the cut-off in the case of the percolation tank is just to prevent erosion of the downstream slope of the bund. The cut-off should be shallow enough to permit the percolating water to pass downstream into the aquifer. The percolation tanks of Maharashtra have, on an average, a larger storage capacity than the *rapats* of Rajasthan.

4. Drinking Water Purification

For drinking purpose rain water is considered to be the purest. And compared to surface water, ground water is more preferred. Water directly from tanks meant for irrigation is never used for drinking purpose. Every tank has a well near its periphery or bund. Water taken out of well which is predominantly seepage from the tank is considered to be pure because of the filter action of soil. Also in the case of *Khadin*

small pits about 5 to 6 feet deep are dug in the bed to draw water for drinking purpose. Water taken from *Chua* is filtered in the riverbed. The same technique is known as 'French Well' in modern engineering terms, where the water is drawn from beneath the riverbed.

4.1 Purification Method

Broadly speaking, purification process contains four major steps, viz., storage, coagulation, filtration and disinfection, although the actual practice vary according to need. These steps are both methods in themselves as well as steps in the whole process.

Storage is the simplest method to purify water. During storage the suspended particles are allowed to settle down and the clear water at the upper layer is taken into another utensil and, if needed, water is purified further otherwise consumed.

Coagulation: Masur, Jowar, Potato, Singhara and Drumstic are used as coagulants. Some of the practices are for example seeds from the Nirmali plant are sliced and rubbed around the sides of earthen pots or they are crushed to make a paste, which is added to water and after stirring alum is added. This process fastens the process of settlement of suspended particles. After due storage water is taken out.

Filtration: The simplest method is cloth filtration. A more sophisticated method is 'pot-filtration' (Fig. 6). Four earthen pots having small hole in the bottom are put on the top of one another. In the first pot pebbles are put, in the second one sand, the third charcoal and the fourth pot collects the filtered

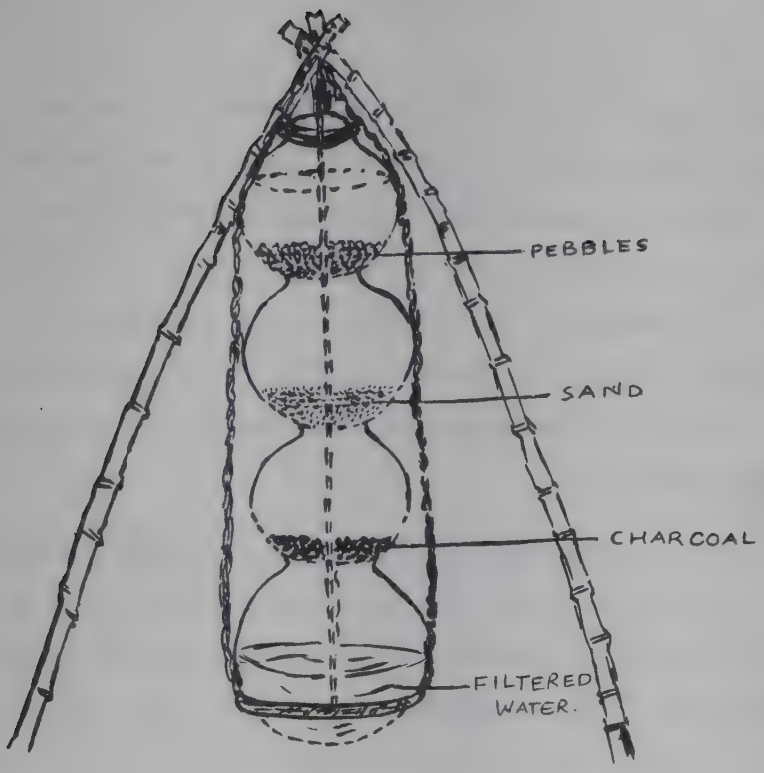


Fig. 6

water. Water from upper pot trickles down to the next lower pot.

With this method even slightly contaminated water can be purified.

Disinfection: A number of plants having medicinal value are used for this purpose. For example, heartwood of acacia, bark of cinnamon, seeds of cardamon etc. The method of treatment may be boiling water with plant, adding paste of leaves to water, rubbing leaves to pot.

5. Water conservation for irrigation

In the water scarce regions there are methods developed to economise every drop of water. Indigenous drip methods are used in several areas. Bamboo-drip irrigation found in north-

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eastern states is an interesting example. During the winter season crops require watering but springs are too dry to spread water over large area. Bamboo pipes (channels) with elaborate network are used to tape the springs flow at a rate of 18 to 30 liters per minutes. The network is so arranged that water is supplied in drops at feild level. This is acheived by manipulating the levels of bamboo channels and by choosing bamboo of different diameters.

In some areas pitchers with fine holes at bottom or on surface are burried near root zone area. The water is regularly supplied through mouth. The water seepage maintains soil moisture necessary for plant growth.

Excess Water Control

It is said that the art or science of water management is to reduce non-average events of drought and flood . In the humid regions after heavy downpour water rushed in a terrential flow eroding the soil in its path to make lowland unusable for cultivation. In dry months water is in deficient supply for irrigation. Here the management task is of rejecting excess water to utilize it for irrigation. The technological principle of combined irrigation and drainage has been overlooked by the modern irrigation theories. This type of irrigation, according to S.Y. Krishnaswamy, is where every field acts as a reservoir and an insurance against the flood.

The diversion structure like *kuhls*, *pynes* play important role in dissipating the flood. *Kuhls* serve to contain rapid flash flow and prevent lower valley from flooding also reduces the damage caused by rushing water. *Pynes* conveys the water for storage of hundreds of small tanks which retain much of the flowing water thus reducing the danger of flood. Roughly the total storage capacity of the *ahars* of the south gangetic plains of the Bihar plateau, approximately 10,000 in number, is about

1000 cubic meters, almost equal to the storage capacity of the Hirakund dam of Orissa. These *ahars* collect runoff of over 20,000 sq km of area and protect the lower part of valley from flooding. Subsequentley water stored in *ahars* is utilized for irrigation purpose.

1. The Kaveri system

At the upper *Anicut* where the river bifurcates into two branches, the northern arm Coleroon carries the bulk of flood waters to sea and the southern arm Kaveri is the main canal for supply of irrigation water to the delta. Below the *Anicut* the Kaveri river branches into numerous arms that irrigate between them over a milion acres. Besides the numerous rivers that traverse the area, several irrigation channels were created over a long period with wide mouths and large sections. The channels have been so designed to take very much more water than is necessary for the land irrigated under them. As a result when there is high flow in the river these channels act as flood draining mechanisms and distribute it among the various fields over the entire delta. Thus preventing the concentration of water in any particular area. As on date 1500 such main channels with their branches and sub-branches run to a total length of about 24,000 km.

The other important point is the design of the system at village and field level on the basis of same principle of combination of irrigation and drainage. The drainage channel of upper village is the irrigation source for the lower village. When the river level goes down these channels drain the waters gradually back into the river.

2. Elas

Kerala state lies in the humid tropics. The mean annual rainfall ranges from 200 cm in the south to more than 400 cm in the north much in excess of the annual potential evapotranspiration values ranging from 120 to 150 cm.

In the local language the word *ela* is used to designate paddy fields. *Elas* are continuous stretches of plain land of valley bases interlocked with hillocks. The slopes of the hillocks vary from 5 to 20% . Most of the *elas* have mean area of 200 to 400 ha and have long narrow irregular shape. The geologic history at land of *ela* areas suggest that they started from gully formation by small flow of surface water from hills and mountains and attained the present stage of development. These areas are filled up by recent to sub-recent materials which are mainly composed of sand and silt with decomposed argillaceous materials. Due to erosion and abrasion caused by the river action these material form a cover of impermeable beds. On the surface of beds the paddy cultication is mostly seen. Also sediment and nutrients brought in these *elas* from the upper reaches of watershed make the paddy fields highly productive.

During monsoons the runoff from the watersheds of surrounding hillocks collect in the fertile land of valley and floods the area. Such floods generally linger for two to seven days and damage the crop. The traditional soil conservation cum irrigation technique of *ela* was developed to combat the above problem. The technique consists of high level storm water drain dug on either side along the slope of the valley known in local language as *Thodu*, which collect the rain water from

upland of the watershed. At the lowest portion of catchment and from beginning of the valley series of tanks are constructed to take excess water from storm water drain. Any surplus water comming into tanks flows back into drain. As a result the deepest and most fertile portion of the valley is protected from flooding and made available for cultivation.

3. Ancient System of Irrigation in Bengal

The system known as overflow irrigation has been described in detail by Sir William Willcock. These systems were believed to be constructed by Chola Kings of Bengal some 2000 years ago in Ganges and Damodar delta, inspired by Egyptian irrigation system on Nile river.

The technique consists of long, continuous canals fairly parallel and at equal distance to each other. They were broad and shallow, at the head carrying river water and at their tail carrying rainwater drained through the fields. The irrigation was performed by breach in the banks of canals which were closed when the floods were over.

After the heavy rainfall when rivers receive floods the banks embanked with mud were breached, at appropriate time and the flood water was taken into the canals. The flood water if not diverted at appropriate time can create havoc by inundation. The heads of the canals were so arranged that the upper muddy layer of water from river floods rich in fine clay and free from course sand enter the canal.

As such rainfall is sufficient in both region for rice cultivation. But the land cultivated is composed of light silt which can be easily eroded, soon become dry and is in need of irrigation

of clayey water. The supply of river water was far in excess of actual requirements. The early flood water being muddy and clayey has fertilizing effects to the fields and any amount in excess improves the soil.

Apart from the engineering marvel to drain the excees water for irrigation purpose the distinct ecological niche created by overflow irrigation brought health and wealth to the region. After the rainfall the dry and barren plains become damp and mosquito larvae begin to breed in millions. At this times the muddy waters of river come with thousands of eggs of fish. The eggs travel down the canals and reach the rice fields full of rain water. The young fish live on larvae of mosquitoes and thus combat the malaria. Fish being rich source of protein bring health in the region.

The cuts made in the rain river bank as heads for overflow canals were called '*Kanwa*' in Damodar delta the channels were called '*Kana Nudee*' in Huggly delta they were known as '*Kana Nudee*' or '*Kunti Nudee*' and '*Kintool Nundee*'. Also '*Kani Nudee*' and '*Kana Dalkishar*' names used for the same.

Over the centuries this system served the purpose of irrigation cum drainage. But when British took over the region in late ninteenth century they were already in ruined shape. All the canals were converted into long chains of stagnent pools of water breeding malaria and poverty.

Conclusion

The list of systems included is not exhaustive as it is beyond the scope of the book. Many such systems with amazing technical sophistication are still to be studied. There are very few studies available on the engineering aspects such as site selection, design consideration, construction methods, material used. A more thorough enquiry and detailed examination by the trained personnel is the need of the hour.

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Congress on Traditional Sciences & Technologies of India

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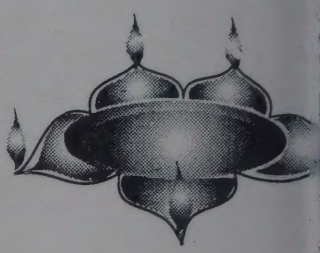

The realisation that the modern scientific and technological paradigm does not offer viable solutions to many vexing problems of today has sparked off a world-wide search for 'alternatives'. In this context, India is uniquely placed in that she had a vibrant tradition of not just isolated techniques, but a complete integrated structure that evolved independent of the modern system. Further, this tradition continues to be practised widely even today.

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The genius of Indian tradition has demonstrated how in a country with such diversity in topographic and agro-climatic conditions, it is possible to make maximum u tion of the erratic monsoon in several ingenious ways for a reasonably settled and prosp life. These practices which were evolved through centuries, have developed the techn of water management to a fine art, from the Great Kaveri Anaicut to the roof top harvesting systems of Rajasthan.

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